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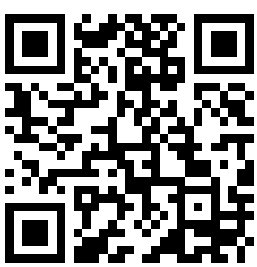

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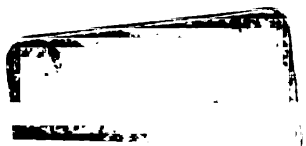

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THE UNITED STATES
STRATEGIC BOMBING SURVEY

POWDER, EXPLOSIVES, SPECIAL ROCKETS AND JET PROPELLANTS, WAR GASES AND SMOKE ACID

(MINISTERIAL REPORT No. 1)

STANFORD UNIV. JUL 1947 DOCUMENT DIV.

OIL DIVISION

JANUARY 1947

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THE UNITED STATES
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(MINISTERIAL REPORT No. 1)

OIL DIVISION

First Edition 5 November 1945
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This report was written primarily for the use of the U. S. Strategic Bombing Survey in the preparation of further reports of a more comprehensive nature. Any conclusions or opinions expressed in this report must be considered as limited to the specific material covered and as subject to further interpretation in the light of further studies conducted by the Survey.

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Foreword

The United States Strategic Bombing Survey was established by the Secretary of War on 3 November 1944, pursuant to a directive from the late President Roosevelt.

The officers of the Survey were:

Franklin D'Olier, Chairman.
Henry C. Alexander, Vice-Chairman.

George W. Ball,
Harry L. Bowman,
John K. Galbraith,
Rensis Likert,
Frank A. McNamee, Jr.,
Paul H. Nitze,
Robert P. Russell,
Fred Searls, Jr.,
Theodore P. Wright, Directors.

Charles C. Cabot, Secretary.

The Table of Organization provided for 300 civilians, 350 officers and 500 enlisted men. The Survey operated from headquarters in London and established forward headquarters and regional headquarters in Germany immediately following the advance of the Allied armies.

It made a close examination and inspection of several hundred German plants, cities and areas, amassed volumes of statistical and documentary material, including top German government documents; and conducted interviews and interrogations of thousands of Germans, including virtually all of the surviving political and military leaders. Germany was scoured for its war records which were found

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sometimes, but rarely, in places where they ought to have been; sometimes in safe-deposit vaults, often in private houses, in barns, in caves; on one occasion, in a hen house and, on two occasions, in coffins. Targets in Russian-held territory were not available to the Survey.

Some two hundred detailed reports were made. During the course of its work, the Survey rendered interim reports and submitted studies and suggestions in connection with the air operations against Japan.

While the European War was going on, it was necessary, in many cases, to follow closely behind the front; otherwise, vital records might have been irretrievably lost. Survey personnel suffered several casualties, including four killed.

The Survey studied the effects of the air attack on Japan and further reports have been submitted to the Secretary of War and the Secretary of the Navy.

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MINISTERIAL REPORT NO. 1

POWDER EXPLOSIVES, SPECIAL ROCKET AND JET PROPELLANTS, WAR GASES AND SMOKE ACID

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

I. INTRODUCTION, SUMMARY AND CONCLUSIONS

1. This report presents an overall study of Germany's production of explosives, propellants and related chemicals for direct consumption by the Armed Forces. It corresponds in scope with the German PSV (CR) Program, which included powder, explosives, direct raw materials, war gases, smoke acid and special rocket and jet propellants. It is based mainly on information obtained from ministerial, army staff and special committee sources, but also contains a fair amount of information abstracted from US Strategic Bombing Survey target reports for related plants.

2. From 1933, explosives and pwder manufacturing capacity was expanded practically continuously until the end of the war by the construction of government owned plants. Capacity for the manufacture of war gases, smoke acid and special propellants was similarly expanded up to the last few months of the war.

3. It was anticipated that these important plants would certainly be bomb targets, so the Germans built a large excess of capacity dispersed well over the country. During the earlier years of the war fairly large stocks of powders, explosives, complete munitions, rocket propellants and war gases were built up.

4. With regard to the essential raw materials, such as methanol, ammonia, ethylene oxide, toluene, etc., the Germans were not as farsighted. They depended largely on chemical manufacturers for these materials, and production was concentrated mainly in a few large chemical plants, such as Leuna, Ludwigshafen-Oppau, Linz, Heydebreck and Waldenburg. Apparently the Germans depended almost entirely on their large existing production capacity for raw materials and intermediates, as little or no stocks were accumulated in preparation for the war. This was the most vulnerable part of the entire set-up.

5. By suppressing the manufacture of methanol and ammonia the intensive bombing attacks on the important hydrogenation plants producing aviation gasoline at Leuna, Oppau and Heydebreck had a profound effect on Germany's powder and explosives production. This was an unintentional and unrecognized bonus of the attacks on oil. In spite of extreme measures (including the dilution of high explosives with inert extenders, such as rock salt, to the extent of 60 to 70 per cent by weight, with consequent depreciation in effectiveness), a serious shortage in munitions occurred. In February 1945, munitions output had dropped to about one-third of that in October 1944. In particular there were critical shortages in ammunition for field artillery and flak. This, of course, meant less resistance for our bombers.

6. The bombing of the large chemical plants resulted in a sharp decrease in the production of smoke acid and thereby limited the Germans' ability to screen their vital installations from view of our bombers.

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

7. The powder and explosives industry was never selected as a target for intensive strategic bombing. Late in the war, a few plants were hit by casual attacks, but by that time production had been so greatly curtailed by raw material shortages that the direct attacks were almost without effect on the overall production picture. From the few plants that were bombed, it appears that incendiary bombs would have been very effective in producing secondary explosions, particularly if mixed with moderate quantities of high explosive bombs to open buildings. By bombing seven of the largest explosive plants it would have been possible to eliminate 70 per cent of Germany's TNT production. The two plants which produced powder stabilizers represented a bottleneck, the destruction of which would have practically stopped powder manufacture in a few months.

8. The bombing of the Hollri egelskreuth plant which manufactured concentrated hydrogen peroxide, an oxygen carrier for rocket propellants, had little effect on the production of that material, since the concentrating equipment was undamaged and the plant could be supplied with 30 per cent of necessary material manufactured elsewhere. The large unprotected plant at Bad Lauterberg would have been an excellent bombing target, as so much production of H_2O_2 was located there. Concentrated nitric acid, important as an oxidizing agent for rocket and jet propellants for the expansion projected for 1945 and 1946, was seriously short because of the destruction of ammonia plants.

9. Germany's manufacture of war gases and its capacity to wage gas warfare was seriously limited by the bombing of plants making chemical raw materials.

10. By the time the Germans recognized the vulnerability of their chemical raw materials supply, it was too late to do anything about it. The following are quotations from captured German documents and interviews with important leaders:

11. German Air Force Staff, Plans Division No 1337/44. 25 April 1944. "The production of nitrogen, methanol, Buna and fuel are critical points of attack. These are basic materials which are inherently bottlenecks, due to the huge quantities required, together with the fact that they are manufactured in a very few large plants. Within the chemical sector these might be first choice for a 'short term' target."

12. "About 30 per cent of the production of nitrogen is concentrated in the two large plants at Leuna and Oppau (near Ludwigshafen) and 15 per cent to 20 per cent in three other plants in the Ruhr area; accordingly more than 75 per cent is concentrated in the five plants mentioned. In the course of this year, Heydebreck (Upper Silesia) will be added to these, with another 20 per cent.

13. "A very great part of the production of powder and explosives depends upon nitrogen; as well as the synthetic fertilizer supply for agriculture... The supply situation in both cases is seriously strained.

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Methanol production is distributed as follows: 60 per cent at Leuna, 15 per cent at Oppau, 25 per cent at Heydebreck; this year Auschwitz (Upper Silesia) will be added to these with a percentage equal to that of Heydebreck. Methanol is a basic material for the manufacture of explosives, hexogen and toluol..."

14. In their evaluation of Allied air attacks, they explained the fact that critical chemical and transportation targets were not attacked earlier on the assumption that such attacks prior to invasion would help the Russians more than the British, and that such targets would be attacked when the time became ripe for "decisive action to win the war for the British."

15. The following quotations are from the same source (No 6262/44 8 Nov 1944). "The production of explosives was also hit in increasing measure, particularly via the bottleneck plants of nitrogen and methanol production."

16. (No 6800/44 10 Dec 1944.) "It becomes clear that the enemy intends to destroy the German production of explosives. For this purpose the bottlenecks nitrate and methanol have been the object of systematic attacks, directed not only against hydrogenation plants and plants producing synthetic gasoline, but also against all other plants which are of any importance for these products. These attacks, which become more and more clearly defined, hit the German supply of ammunition in its most vulnerable spot and serve very effectively to bring relief to the ground forces of the enemy."

17. "As far as the chemical industry is concerned, the attacks will continue to be directed against the production of liquid fuel and -- partly identical with it -- against the bottlenecks in the production of explosives. Thr eatened are, in the first place, Leuna and Oppau, in addition, Linz and all other plants of this type in the Ruhr area and Silesia."

18. Memo of conference with Dr. Ritter of Gebechem on 31 Oct 1944: "Fears for the future are therefore concentrated primarily upon the nitrogen methanol plants. In this respect the explosives supply is most susceptibly endangered, by far more than through possible attacks upon the explosives plants themselves. With nitrogen and methanol only a small number of great plants of higher sensitivity to air attack are involved."

19. "It will take until summer of next year to reduce the air vulnerability of the se plants through special measures of air defense construction."

20. "With the explosives plants, there are a great number (50 to 60) of separate plants, which are distributed over the country, well camouflaged and rendered considerably less vulnerable to air attack by

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the design. The destruction of Clausthal, an older plant, is considered an exception by IG."

21. Hitler publicly rebuked Dr. Krauch for concentrating ammonia and methanol production in the few large plants. (When the first big plant was built at Leuna, Ludendorf had advocated underground construction.)

General Henrici stated, "If Allied effort had been concentrated on ammonia plants, Germany could have been knocked out of the war a full year earlier."

22. It is believed that a serious mistake was made in not selecting ammonia and explosives plants as primary targets. Elimination of either of them at earlier stages of the war would undoubtedly have meant an earlier defeat of Germany. It is difficult to understand why these targets were neglected. Destruction of the productive capacity of hydrogen peroxide plants, of which there were only two, would also have seriously affected the capacity of the Germans to wage rocket war.

II. POWDER AND HIGH EXPLOSIVE INDUSTRY

1. Foreword

a. For a clear appreciation of the effect of strategic bombing on the German powder and explosives industry, a knowledge of the interrelation of this industry with, and dependence upon, the synthetic ammonia, methanol and oil industry is necessary. Methanol and ammonia are important raw materials, as shown in Exhibit R in the Appendix. These three synthetic manufactures were all high pressure processes which required a source of large volumes of hydrogen of a high degree of purity, using the same type of equipment. In fact the same equipment was used for the production of methanol and ammonia in some German plants, and in several cases all three processes were conducted in the same works. The bulk of the ammonia and methanol syntheses was concentrated in a few plants. In certain plants, it was planned, when the synthetic oil facilities were installed, that they should be dependent in part, on hydrogen capacity installed previously for ammonia production, when full capacity ammonia operation was not required. For this reason, in such plants there was insufficient hydrogen production capacity to operate to capacity all three syntheses simultaneously. Consequently synthetic ammonia production never reached the full capacity for which the plant was designed. Hydrogen was allocated to the three syntheses according to the relative demands for the products at the time. At that plant, aviation gasoline was given priority until November 1944, when ammonia was given a top priority.

b. The production of powder and explosives was bound to the manufacture of synthetic ammonia and methanol in three ways. All the

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principal explosives and propellants (exceptions were the initiating or primary explosives, lead azide and styphnate, and mercury fulminate) depended on nitric acid or nitrates in one form or another for their production. Synthetic ammonia was the main raw material for the production of nitration grade nitric acid. Two of the most modern and effective explosives, hexogen and penta, required formaldehyde, which in turn was made from methanol, which was also used in important quantities for the synthesis of toluene for TNT. In the first half of 1944, about 36 per cent of the total synthetic ammonia and 41 per cent of the methanol went to the production of explosives and propellants. The principal competitor for ammonia was the fertilizer industry.

c. When the large synthetic oil and chemical plants were bombed with the object of knocking out synthetic oil production, ammonia and methanol production suffered directly by destruction of equipment and indirectly by shift of priority of production and repair to oil. As a result the explosives industry was brought practically to a standstill by the bombing of four larg e chemical plants (Leuna, Oppau, Linz, Heydebreck) just as certainly and with less effort than had the 12 large plants making concentrated nitric acid, the 35 powder and explosive plants, or the 5,000 munitions plants been bombed.

d. This report deals with the well organized powder and explosives industry in the first section and covers special rocket and jet propellants and war gases in the two subsequent sections. A brief technical discussion of the manufacture of powders and explosives, composition of compounded explosives, and full data on production are included in Part B of Section I; the filling of munitions will be treated briefly in this section.

2. Review of the industry in Germany prior to the war

a. At the close of World War 1, the highly organized German powder and explosives industry was largely dissolved. By the Treaty of Versailles materials which could be manufactured were limited. The following figures indicate the size of the industry at the close of World War 1. (Figures are given in metric tons per month):

	Planned production, Hindenburg program (tons per month)	Maximum actual production
Powder	18,000	12,000
Explosives	36,000	20,000

b. Powder plants were located at Reinsdorf, Premnitz, Duneberg, Rottweil and Haslock, and explosives plants at Krummel, Domitz, Schlebusch

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and Clausthal-Zellerfeld. A plant at Troisdorf produced nearly the entire output of lead azide and detonators. The map charts of Exhibits D and E show that the powder and explosive production, excluding initiators and detonators, was well dispersed.

c. During the early peace years, the powder plants at Reinsdorf, Haslock and Rottwell and the explosives plants at Krummel, Domitz and Schlebusch were permitted by the Versailles Treaty and Allied Governments to make mining explosives, nitrocellulose powders for sporting purposes and a limited quantity of military explosives. Most of the factories producing nitrocellulose turned to the manufacture of celluloid plastics, films, rayon, sausage casings, lacquers, etc., for which their equipment was readily adaptable.

d. Complete detailed data for production, imports and exports of powder and explosives during the period 1918 to 1932 were not obtained, but it was estimated by Dr. Diekmann, of Gebechem, and by the British Economic Advisory Branch, Ministry of Economic Warfare, that the volume of production ranged from approximately 1,000 to 2,000 tons per month. The Haslock plant was permitted to produce sporting powders to the extent of about 49 tons per month and the Schlebusch plant 1,000 tons per month of TNT and 800 tons per month of nitroglycerin.

e. The industry, during this period, was very largely owned and operated by private corporations. The dominant firm in the explosives field was Dynamit AG (DAG), organized in 1926 from the Alfred Nobel Co. It was controlled by I.G. Farbenindustrie. Second place in the field was held by Westfalische Anhaltische Sprengstoff AG (WASAG), another combine which manufactured both powders and explosives. Wolff and Co., AG of Walsroder, and I.G. Farbenindustrie subsidiary, and Lignose, GmbH, were smaller units. Exhibit A1 shows the financial structure of the main corporations as presented by the British Ministry of Economic Warfare in its Economic Survey of Germany, Section X, Armaments and Munitions.

f. The capitalizations quoted in Exhibit A1 are considered by no means representative of the extent of participation which the various organizations were to have later in the wartime industry. The organizations were essentially management enterprises, and as such needed no capitalization for plant, property, raw materials or manufacturing costs. Their combined capitalization was probably between RM 25,000,000 and RM 30,000,000 but they controlled, through operation, plants which as early as 1942 represented an investment of approximately RM 2,000,000,000.

g. Although both explosives and propellant powders were manufactured by both DAG and WASAG, it may be said in general that the former specialized largely in high explosives and the latter in powders. In the pre-war years, the powder plants were closely in-

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tegrated with nitrocellulose plastics and lacquer plants. The few small-scale plants which operated were fairly well diversified. The industry was very small and relatively unimportant in the German economy as a whole. Most of the products were used by civilian and industrial consumers. Labor requirements were small. The industry was practically independent of imports of raw materials.

3. Planning for the Industry in Anticipation of War

a. The importance of powder and explosives with regard to Germany's ability to wage modern warfare is obvious. Almost without exception offensive and defensive weapons employed one or both.

b. Evidence from dates on captured German munitions and powder charges indicated that the Germans began expanding their powder and explosive production and accumulating stocks for World War II as early as 1933. These operations were kept secret at first. Single-base nitrocellulose propellants were favored in the early years because they were simple to manufacture and did not necessitate the construction of complicated nitroglycerin plants. Later, when secrecy was abandoned, there was a return to a double-base propellant embodying nitroglycerin and/or diethyleneglycol dinitrate (POL powder). TNT production was greatly expanded in plants which formerly produced only industrial explosives.

c. In 1932, Montan Industrie Werke GmbH, a state-owned corporation, was organized under control of OKH-WaA (High Command of Army Weapon Office) to construct plants for, and coordinate the production of, war materials in secret at a time when it could not be done openly. The first director was Dr. Zeidlehack, who was succeeded in 1940 by Dr. Schiffler.

d. The expansion which followed in the powder and explosives plant capacity obviously could not be justified on the basis of a peace time economy, so the new construction was very largely, if not entirely, paid for by the government. The Ministry of War (RKM) and later the High Command (OKW-Wi Stab) determined the policies and aims as to the volume of production to be achieved, and passed them to the Army Weapons Office (HWA) for execution. Montan built the new facilities with government money. The Generalbevollmachtigter fur Sonderfragen der Chemischen Erzeugung (Gebechem or GB Chem), established in 1936 under the leadership of Dr. Krauch, planned and controlled the construction of plants and the allocations of construction materials and labor to them. The finished plants were leased to the established powder and explosives manufacturers, WASAG, DAG and Wolff. These firms created subsidiaries for the operation of the war plants; for example WASAG organized Deutsche Spreng-Chemie; DAG organized Gesellschaft zur Verwertung Chem Erzeugnisse; and Wolff formed Eibia. The subsidiaries had a capital stock of RM 1,000,000 each. While there was some overlapping, the production of DAG was preponderantly explosives and WASAG and Wolff powder propellants.

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Development of Manpower Employed in New Gebechem Plants for Construction and Building

Date	Oil	Chemical industry	Light metal	Explo-sives	Total
1936) 1937)	No demands for more men -- from the firms to Gebechem. Estimated total figure, 140-170,000.				
1938) 1939)	The construction -- and building -- firms could organize enough men without help from Gebechem. Estimated total figure, 160-200,000.				
15 Aug 1940	65,800	25,200	17,900	92,100	201,000
15 Nov 1940	73,600	24,600	20,300	97,600	216,000
1 Jan 1941	72,500	24,500	18,000	99,000	214,000
1 Apr 1941	79,900	29,200	17,800	93,500	220,400
1 Oct 1941	86,100	30,800	16,500	72,600	206,000
15 Mar 1942	86,000	32,200	15,400	45,200	178,800
1 June 1942	-	-	-	-	188,000
1 Sept 1942	106,200	29,800	14,900	39,300	190,200
1 Jan 1943	94,793	36,651	19,110	50,055	189,340
1 Mar 1943	100,100	31,500	19,900	48,400	200,000
In 1944 more and more men diverted from Gebechem to fighter program, etc.					
1 Jan 1944	77,191	31,663	17,199	44,039	170,052
1 Mar 1944	68,254	28,862	16,471	40,626	154,213
1 Apr 1944	68,100	28,500	16,000	40,600	153,200
1 May 1944	(before Geilenberg directive)				105,000*
1 Oct 1944	218,700	26,400	6,300	34,600	286,000

* After Geilenberg directive many men were forced to change over from producing to repairing division (Geilenberg division).

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Manpower Employed in Gebechem Plants (for Operation and Production)

Date	Oil	Chemical industry	Light metal	Explosives	Total
1 June 1942					310,000*
1 Sept 1942	95,000	85,000	35,500	25,500	240,500**
1 Jan 1943	86,910	-	-	22,030	189,340#
1 Mar 1943	80,000	96,000	36,400	30,400	242,800
1 Jan 1944	101,746	89,099	-	27,588	218,433
1 Mar 1944	108,194	87,071	-	27,697	222,692
1 Apr 1944	109,200	86,500	-	25,000	220,700
1 Oct 1944	45,800##	78,400	-	-	124,200

---

* Including 80-100,000 men in powder and explosive plants.
** Including only those primarily in powder and explosive plants.
\# Without men producing light metals (foundation of the "Aluminum Ring").
More than half of producing men changed to the Geilenberg building and repairing sector.

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

The chart of Exhibit A shows the organization for this industry and the functions performed by the government and by private industrial corporations. Although much of the raw materials was derived from established sources in the chemical industry, another government owned corporation, Wifo, constructed some new plants for concentrated nitric acid and synthetic toluene where the ulilization of this excess capacity in peacetime was not assured.

e. The parent comapanied DAG, WASAG, and Farben, trained and provided the supervisors and technical personnel and supplied essential information.

f. Later, a head committee for powder and explosives, Hauptausschuss Pulver u Sprengstoff, was formed under the leadership of Dr. Sarrazin, for the coordination of production activities and the exchange of technical and production research data between companies. Its organization is shown in Exhibit B.

g. The earliest expansions were in the form of increases in production and facilities in existing plants, and the rebuilding and re-equipping of World War I plants. Beginning in 1934, secret planning of new explosive plants was in progress under the code name Wiese. The first of these to be constructed was located at Gusen, and the first section was completed in October 1935.

h. Although the four-year plan did not give a prominent place to powder, explosives, war gases, and their raw materials (apparently because of the secrecy of the German plans for these items) a Schnell-Plan for PSV (quick plan for powder, explosives, war gases and raw materials) was developed in 1936, and 6,000 tons of stell per month was allocated to the expansion of this industry. Planning was continuous from then until the end of the war, and ever expanding except for a pause in 1940-1941. In some cases new and enlarged plans were adopted as often as two or three times in a single year. Some of the steps in the early planning are shown in Exhibit B1, which is a translation of a memorandum prepared by Dr. Ritter, 21 April 1942. Special rocket propellants were added to the program in later years. By 1942, Prof. Brauch estimated that 1,480,000 tons of steel had been invested in PSV program since 1936, or about 12 per cent of the whole Gebechem construction program.

i. The table and chart comprising Exhibit C show the progress of the actual expansion from 1933 to the end of the war. In the four years 1934 to 1938 the powder production capacity had been increased to 5,000 tons per month and total explosives capacity to 13,500 tons per month, including about 5,500 tons of pure high explosives and 8,000 tons of extenders, principally ammonium nitrate. A fair amount of new construction was included in this increase. Actual production was appreciably below the nominal capacity (2,000 tons per month powder and

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2,700 tons per month pure high explosives estimated in 1939 Gebechem production curves). By operation of this expanding capacity from 1933 to the beginning of the war, a stock of 187,000 tons of powder was accumulated.

j. A notable feature of this graph is the step in the curves which occurs in the period 1940-1941. The explanation for this is that after the easy victories in Poland and France the Germans concluded that Blitzkrieg methods required far less munition expenditures than they had estimated, and that further expansion would be unnecessary. However, with the failure at Stalingrad and subsequent reversal in Russia which resulted in costly losses and high expenditures of munitions, the expansion was resumed intensively in 1943. The delay was serious in the case of highly concentrated nitric acid (Hoko), production facilities for which, as for most other raw materials, had lagged behind the powder and explosives capacity from the start.

k. The expansion of the explosive industry is further reflected in the labor requirements for operations as follows:

1934	1,000-2,000
1938	30,000
1944	80,000-100,000

l. According to Dr. Diekmann, who for seven years was responsible for Gebechem negotiations for powder and explosive plants, the policy of the German High Command was to provide a large excess capacity for the manufacture of powder and explosives, with the expectation that it would be a target for Allied bombing. Liberal allowances were made for air raid bunkers to protect the personnel in these plants.

Tables and map charts presented in Exhibits D, E, and F give a more detailed picture of the expansion of facilities for producing powders, explosives and extenders for explosives, respectively. The location of the plants, the name of the firm by which they were operated, and the production capacity completed in December 1939 and September 1944 are given. The production planned for the future in programs existing on these dates is also given. It is evident from the maps that the industry was well dispersed throughout the interior of Germany.

m. The danger zone from which the Germans intended to evacuate their industries was avoided in locating these plants.

n. In the organization of the plants no fixed pattern was followed. A few plants made a wide range of both powders and explosives as well as detonators, fuses and primers, and even performed loading operations. A good example is the Krummel plant, the annual production of which is shown in Exhibit I. Other plants specialized in powders or ex-

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plosives. There were several instances of vertical integration of plants. In most cases the nitrocellulose base was prepared in one plant and shipped as a moist paste to the plant which made the final propellant. For example, the plant at Krummel prepared raw cordite paste, which was converted to solventless cordite propellants, including those of large diameter for rockets, in the nearby factory of Duneberg. Krummel made high explosives and nitrocellulose, and filled shells. Contrary to the US practice of making explosive plants independent of outside sources of nitric acid by providing each with a plant to make concentrated nitric acid by oxidation of ammonia, only Christinastadt, of the many German explosive factories, had a nitric acid (Hoko) plant. A few had equipment for the manufacture of concentrated sulphuric acid from iron pyrites. All factories conducting nitration had acid recovery and reconcentration plants, and some had acid splitting plants for the production of oleum.

o. The building of new munition loading capacity kept pace with the expansion of plants for powders and explosives. Exhibit M shows the location and capacity of loading plants. The fourth column shows that a large proportion of the loading lines were located in plants making high explosives, and nearly all such plants had facilities for filling munitions down to, and including, hand grenades. There was excess filling capacity throughout the war.

p. With regard to raw materials, the German High Command was not so farsighted as they were in creating excess capacity for powder and explosives manufacture. Total dependence was placed on industrial manufacturers of the raw materials, and it was very difficult to obtain appropriations for state-owned plants. Estimates of raw material requirements in the event of war set up in 1939 are as follows:

	Mobilization requirements			Germany's own production
	Wehrmacht	Industry	Total	
	tons per month			
Hoko acid	23,000	4,500	27,500	26,250
Toluene	3,430	650	4,080	3,450
Glycerin	740	580	1,320	288

q. Stocks on hand at the time were 15,600 tons of toluene, 11,000 tons of glycerin and no nitric acid. They estimated that domestic production plus available stocks would fully meet mobilization requirements for nitric acid for unlimited time, and for 25 and 10.5 months for toluene and glycerin respectively.

r. These estimates were very low compared with 1944 consumption, which was about 70,000 tons per month of Hoko acid and 12,000 tons per month of toluene. Exhibits G and H show the capacities and locations of

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plants for the production of the principal raw materials.

s. No great stockpiles of fixed nitrogen in the form of urea or ammonium nitrate were accumulated in anticipation of the war. In 1941-3 the reserve of Hoko acid was sufficient for about 10 days only, partly because of inadequate storage facilities which could not be increased because of lack of stainless steel and aluminum. Toluene stocks were built up to 6,000 tons at Embsen and 5,000 tons at Langelsheim (Wifo). The reserve stock of methanol in 1942-43 was estimated by Dr. Diekmann to be 20,000 tons. Some stocks of glycerol and diglycol, possibly 1,000 tons, were accumulated, but owing to the large consumption of glycol antifreeze in the long Russian winter 1941-42 it was impossible to accumulate much diglycol. Crepe paper (for nitrocellulose production) and pentaerythritol sufficient for about six months were accumulated. From one to two months reserve supply of hexamine was available in 1942-44, but this was used in 1944 when methanol became scarce.

t. The main technical advances to eliminate dependence on imports of raw materials were: (1) the development of DEGN (diethyleneglycoldinitrate) as a substitute for nitroglycerin in propellant manufacture, (2) the development of a process for the synthesis of toluene from benzene and methanol, (3) the adoption of the shell process for the synthesis of glycerin, and (4) the development of new and more economical processes for the manufacture of hexogen. Owing to the shortage of fats and animal and vegetable oils in Germany, a shortage of glycerin existed from the beginning of the armament program. This was alleviated mainly by the substitution of diglycol, which could be made from coal and limestone, and partly by synthesis of glycerin from isopropyl alcohol. Two plants for the synthesis of glycerin were constructed, one at Oppau and one at Heydebreck. Although the bulk of double-base powders was made with diethyleneglycol dinitrate instead of nitroglycerin, 100 tons of glycerin per month, out of a total German production of 600-900 tons per month, was allocated to powder manufacture in early 1944.

u. The shortage of toluene was further alleviated by the adoption of hexogen, which could be made from synthetic methanol and ammonia, as a high explosive. According to German reports it had certain advantages, being sufficiently insensitive for use in armor-piercing ammunition and reportedly 2.25 times as effective as TNT.

v. Another important class of raw materials for powders is the so-called stabilizers -- diphenalimine, diphenyluretane, ethylphenylurethane, akardites and centralites -- which plasticize nitrocellulose and neutralize traces of acid which would promote its decomposition. The production of these stabilizers was to a large extent concentrated in two plants, one in Wolfen and the other in Uerdingen, each having a capacity of 550 tons per month. According to Dr.

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Diekmann, no stocks of these materials existed after 1941. However, one letter found in the Speer Ministry documents stated that a supply of 1,500-2,000 tons, sufficient for two to three months, was available in September 1944.

w. Attempts were made to limit the use of the important raw materials in other than powder and explosive applications, but in most cases it was established that these other products went to the Wehrmacht also and were essential to the prosecution of the war. Industrial consumption of powder and explosives in mining, etc., increased with the wartime expansion of these industries, but their consumption was still small compared to the Wehrmacht requirements. Exports of finished powder and explosives during the period immediately prior to the war were so small as to have no appreciable effect on the accumulated stockpile. Dr. Sarrazin of the Hauptausschuss fur Pulver und Sprengstoff furnished the following estimates of exports and imports:

	Total exports for period	
	1936-1942	1943-1944
Powder	18,000 tons	2,000 tons*
Explosives	35,000 tons	10,000 tons*

* To Finland, Hungary, Bulgaria, Rumania and Italy.

x. Imports amounted to about 11,000 tons nitrocellulose powder. Civilian and industrial consumption were so small as to require no regulation.

y. Technical men were provided and trained for the operation of the new plants by the industrial firms, DAG, WASAG, and IG, who were to operate them. Many foreign laborers and as many as 350 trained chemists, physicists and engineers were procured from Russia, Poland, etc., at first on a voluntary basis. Foreign labor ran as high as 50 to 60 percent later in the war.

4. Performance of the Industry and Changes in Planning up to Mid-Summer 1943

a. The priority position of this industry and the planned production fluctuated from time to time with Germany's military successes. They were high at first, but were reduced after the Polish and French campaigns when it was concluded that blitzkrieg methods required less munitions than estimated previously. New construction of plants was cut in 1940-41 when stocks were piling up. This stock accumulation is shown by the data from Gebechem files as shown in Table 1.

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b. Production was well in excess of consumption and stocks were accumulating. This would check with the British Ministry of Economic Warfare estimate that prior to 1944 the pipeline from powder factory to front line was 18 months. (In early 1945 this had been reduced to less than 12 months.) However, it must be borne in mind that reserve stock figures are likely to be far less reliable and consistent than production data. To begin with, such data depended upon the accuracy and completeness of the reporting of all military supply installations. Such reporting was liable to gross errors in a situation in which an army was being driven back continuously and was suffering heavy losses of supplies.

c. After Stalingrad and subsequent costly reverses in Russia both in expenditure and losses of munitions, explosives and oil were given high priority in mid-1943. Diglycol and Hoko acid had a higher priority than explosives from the end of 1942 to the middle of 1944. Planned production and construction of new plants were expanded accordingly in this period.

d. The best information on production and consumption during this period was found in the S-Buch prepared by the Feldwirtshaftsamt of OKW. A translation of graphs from this is shown in Exhibits J1 and 2. Extenders are included in the total explosives figures.

e. It is evident that production exceeded consumption and stocks were accum ulating. Some difficulties encountered in production during the period were a shortage of platinum as catalyst for the oxidation of ammonia to nitric acid, and a shortage of sulfuric acid owing to the blockade of pyrites shipments from Italy. As a result of the first, the large Hoko (concentrated nitric acid of nitration grade) plants at Wolfen and Hochst had to oxidize ammonia by the old method, using manganese and cobalt oxides. Sulphuric acid was even made from gypsum when pyrites became short.

f. The allocation and consumption of powder and explosives for the three branches of the Wehrmacht from the beginning of the war to the middle of 1943 are shown in Exhibits K1 and K2, taken from the S-Buch of OKW. For the most part production exceeded consumption, but it is not known whether consumption figures included losses by capture and destruction.

g. Exhibit L shows the allocations of the most important explosive TNT by quarters. An export of five to eight per cent of the total production is indicated. Powder and explosives requirements of industries and civilians are very small in comparison with the Wehrmacht consumption.

h. As shown by Exhibit C, expansion of production facilities was taken up intensively and was carried forward to the end of the war.

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Table 1

Accumulation of Powder Stocks

	Powder (total)		
	Production, tons per month	Consumption, tons per month	Stocks tons
Oct 1941	10,000		169,000
Nov 1941	11,601	4,900	
Dec 1941	9,140	4,500	
Jan 1942	9,812	4,900	
Feb 1942	9,417	5,800	
Mar 1942	10,765	7,800	
Apr 1942	10,722	7,600	
May 1942	11,017	4,700	
Jul 1942	12,698	6,600	
Sep 1942	-	-	206,000
Jan 1943	15,457	10,100	
Jul 1943	19,657	18,300	
Jan 1944		19,100	
Jun 1944		17,600	

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

Raw material production facilities continued to lag behind powder and explosives capacity. In July 1942, when it was decided to freeze powder and explosives capacity expansion at the level attained at that time, except for the further expansion of hexogen capacity from 3,200 to 7,000 tons per month, it was recognized that the raw material capacities would have to be increased by the following amounts:

Hoko acid	20,000 tons per month
Methanol	5,000
Hexamine	3,400
Diglycol	600
Stabilizers	500
Nitrocellulose	4,500

i. Plans were made for a stabilizers plant at Moosbierbaum and for a diglycol plant (500 tons/mo) at Auschwitz.

j. Dr. Diekmann estimated that 20 per cent more powder and explosives could have been produced throughout the war had nitric acid been available in adequate quantities. He said that the military men had no appreciation of raw material requirements.

k. No accurate information on the quantities of filled munitions which the Germans acquired by capture were found, but they acquired large stocks of uncompounded nitrocellulose and manufacturing capacity for 4,500 tons of powder per month in France. However, as a result of non-cooperation and sabotage by the French, actual production never exceeded 700 tons per month and after four years most of the nitrocellulose stocks were still unconverted. These plants were put out of operation by bombing and capture in 1944.

l. After the fall of France in 1940 an agreement was made for France to supply Hoko acid in exchange for the equivalent quantity of fertilizer nitrogen. A Hoko plant having a capacity of 2,500 tons per month was moved from Bergerac, France to Ambsen, Germany.

m. Germany took over the powder plant at Pionki in Poland which produced 400-500 tons per month of double-base (DECN nitrocellulose) powders and had a capacity in its Hoko acid plant of 1,000 tons per month. The bulk of its powder output went to the eastern front.

n. Italy got nitric acid and glycerol from Germany in the earlier years, but in 1944 was able to supply 1,000-1,500 tons per month of Hoko to Germany.

o. Workers in Norway struck and refused to make fixed nitrogen for Germany's war production. Germany built three synthetic ammonia plants in the Donetz Basin in Russia, but one to one and one-half years were required for their construction, so it is doubtful if Germany actually realized any benefit from them.

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p. Allied bombing raids on powder and explosive plants prior to the combined bomber offensive were light and sporadic. They had no effect on the production, as the total capacity was never reduced below that of the available capacity for Hoko acid production.

q. Steps which were taken to protect the facilities of the industry in anticipation of intensified bombing were of two classes, passive and active. Of the former class, the first step was the planning and construction of a large excess capacity in well dispersed plants. With regard to the plants themselves, the buildings were well separated from each other and were generally arranged in irregular patterns in a forest. They were provided with reinforced concrete roofs which were covered with soil. Various types of vegetation were grown on the roofs for camouflage. This was considered good, but painted camouflage was worthless, according to Dr Sarrazin. Important and sensitive apparatus was located in deep cellars with reinforced concrete walls as far as possible. Fragment protection walls of reinforced concrete, sand bags, etc, were provided for the central power plant, working rooms and important equipment located above ground. Air raid shelters of reinforced concrete were provided.

r. The above types of protection against fragments were considered very effective. Good blackout control and decentralized fire fighting equipment were provided. Smoke was not used. Balloons were tried on a few of the bottleneck plants at first but were abandoned later. No decoy plants were constructed. According to Dr Sarrazin the active measures consisted entirely of light and heavy flak. However, there was no evidence of flak protection in the plants surveyed and no mention was made of flak protection by plant directors in their reports to the Rustungskommando. The light flak proved useless. Heavy flak was not favored because of possible destruction by falling fragments. Apparently insufficent priority was given these plants to obtain fighter protection.

5. Performance of the Industry and Changes in Planning During the Course of Combined Bomber Offensive as a Result of Both Direct Attacks and Indirect Attacks

a. In 1943, 1944 and 1945 the Germans had planned to increase both powder and explosives production. During 1943 production of powder was close to the plant capacity and the explosives production was high, although not quite approaching the limit of capacity. These rates of planned production continued through the first half of 1944 and were made possible by diverting nitrogen originally budgeted for fertilizers into the powder and explosives industries. The agricultural consumption of greater Germany in 1938-1939 was 19.3 lbs of nitrogen per acre. In 1943-1944 agriculture received 10.25 lbs per acre and in 1944-1945 the allotment was only 4.45 lbs per acre. After mid-year 1944 it was apparent that the use of fertilizer nitrogen by the explosives industry would

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not overcome shortages and, in the case of explosives, planning approximated what appeared reasonably possible to attain. Due to the fact that the bombing of powder and explosives industries occurred, for the most part, very late in the war, decreased production was largely the result of attacks on the chemical and oil industries and on the transportation system. Ammonia, methanol, toluene and ethylene oxide were the main raw materials affected.

b. These attacks on the chemical and oil industries affected the production of explosive s and powder in at least two ways. The raw material supplies were reduced and workers were withdrawn from the explosives and powder plants to aid in the repair of the chemical and oil plants. One hundred thousand men were sent from Gebechem to the Geilenberg agency, 20,000 being from the operating staffs and 80,000 from construction crews. A proportion of these came from the powder and explosives industries. Labor was also shifted to the fighter plane program, which had a higher priority than powder and explosives. The exact number to each is not known. As a result of withdrawal of labor it was necessary to stop new construction of powder and explosives plants and to postpone indefinitely the completion deadlines. However, as a result of the bombing of methanol and ammonia plants, the supply of these essential raw materials had been reduced far below the needs of existing powder and explosives plants by late 1944, and the stopping of construction was therefore unimportant.

c. The relationship between reported plant capacities, the planned production and the actual monthly production from January 1943 through February 1945 are shown in the Figures I, II, III and IV. The plant capacities reported, 1934 through 1945, are given in the table and chart comprising Exhibit C. Tables II and III give the production data plotted in Figures II and III respectively.

d. In Figures I, II, III and IV, the heavy solid line represents the designed plant capacities, in totals, for the respective materials, high explosives, powders and explosive-type extenders. The light solid lines represent the actual production, whereas the dotted lines portray the planned production.

(1) Chart II, High Explosives: The production curve for high explosives lines reasonably close to the capacity limit until mid-1944, despite the fa ctthat bombing of oil plants, synthetic methanol plants and liquid oxygen plants had necessitated the removal of synthetic ammonia equipment for the restoration of a part of the production of these other important war materials (see reports on the effects of the bombing of the chemical industries). This cannibalizing of the ammonia plants, together with air raid damage inflicted on the plants as primary targets or when nearby targets of other sorts were hit,

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EXPLOSIVES PRODUCTION BY TYPE

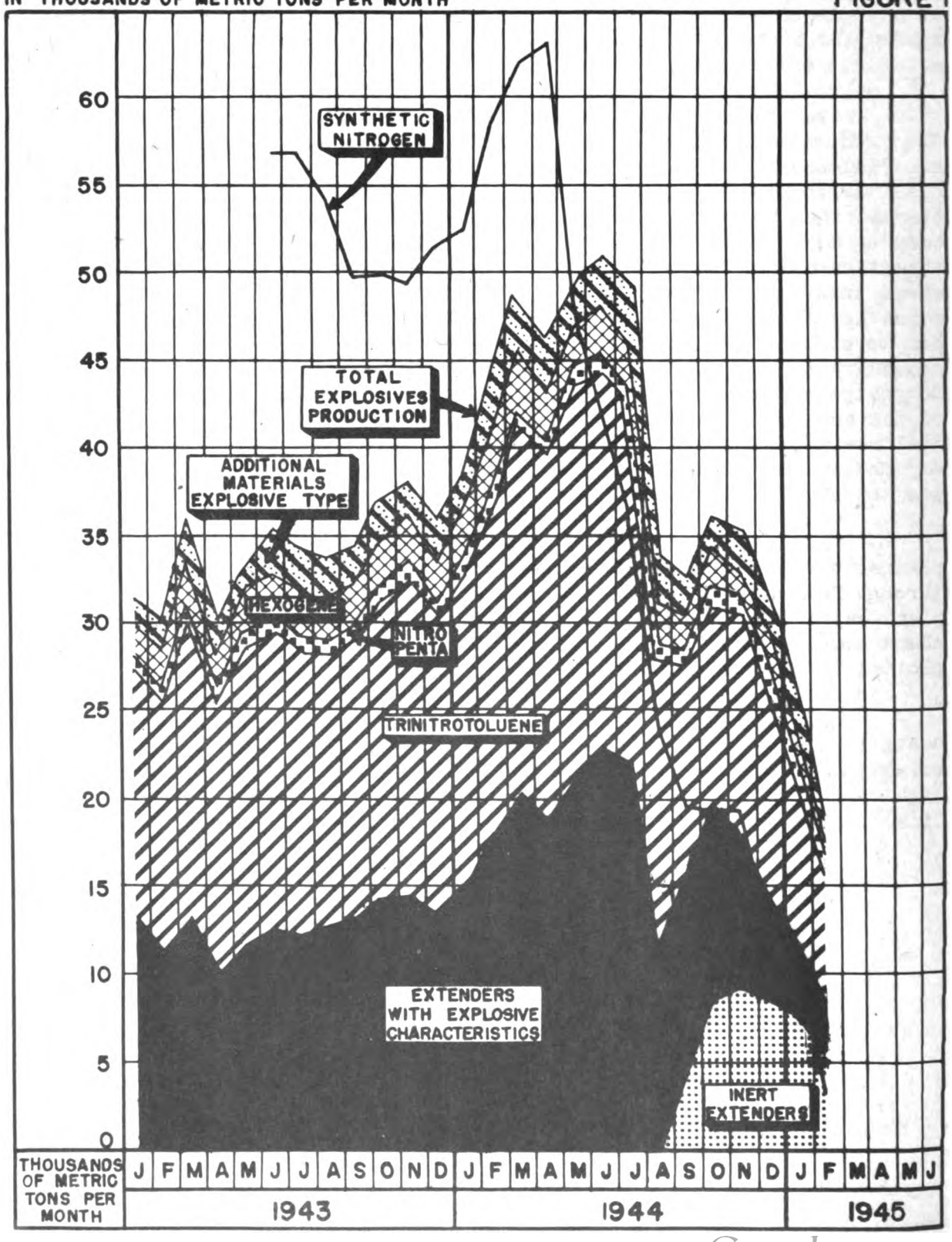
GREATER GERMANY

(INCL. OCCUPIED TERRITORY EXCL. ITALY)

SOURCE SPEER DOCUMENTS

IN THOUSANDS OF METRIC TONS PER MONTH

FIGURE I



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GERMAN HIGH EXPLOSIVES PRODUCTION

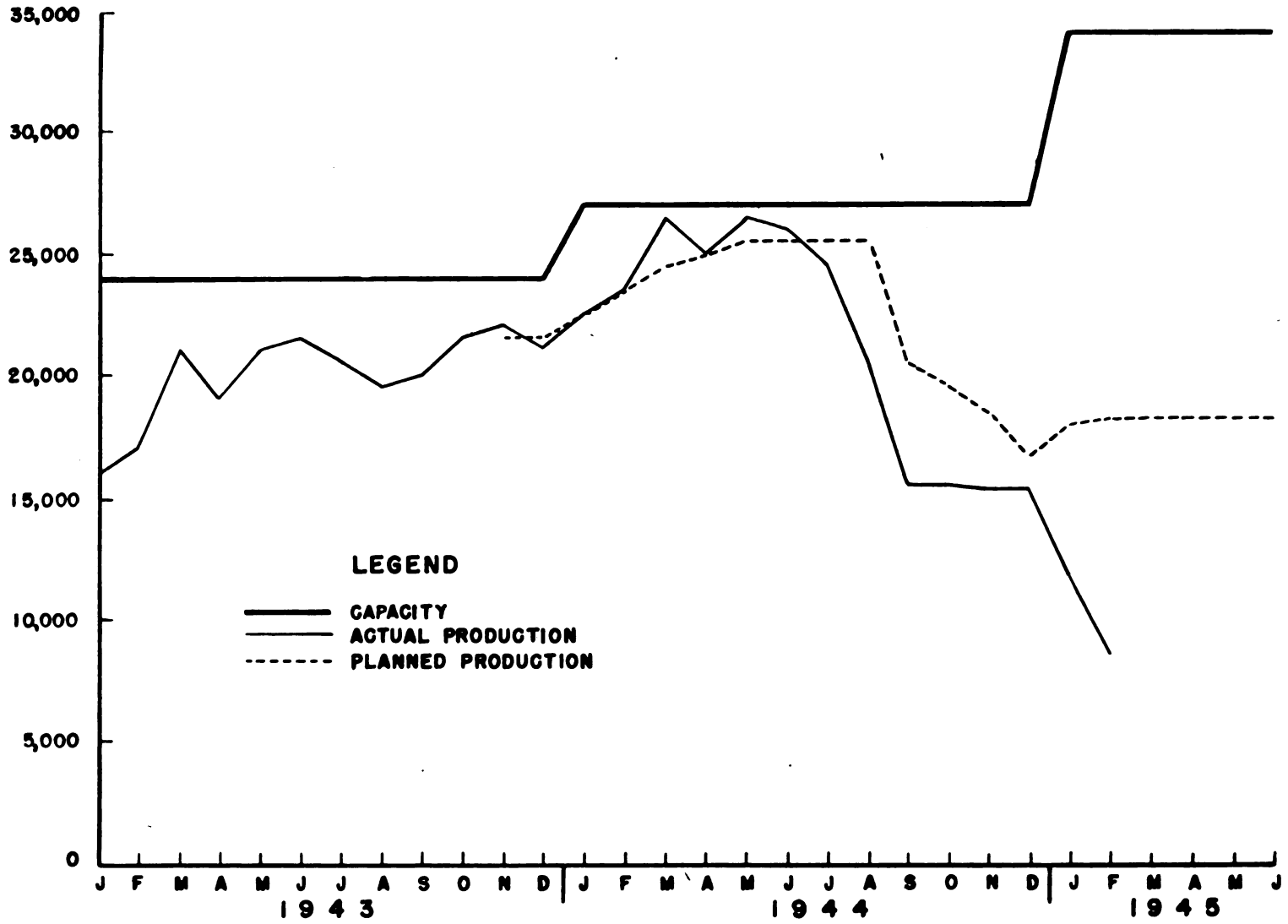

FIGURE II

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GERMAN
EXPLOSIVE EXTENDERS
(AMMONIUM NITRATE)

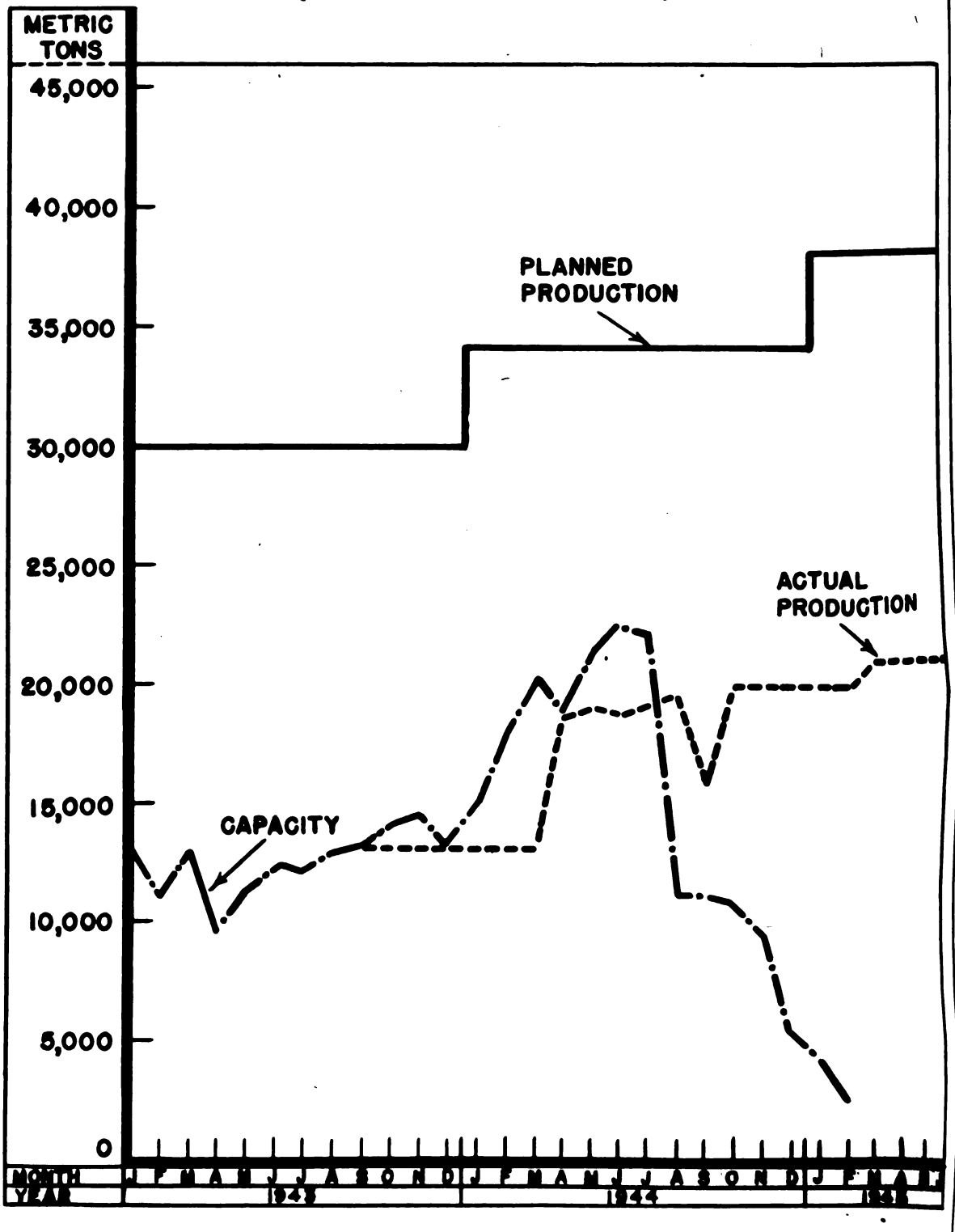

FIGURE III

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GERMAN POWDER PRODUCTION

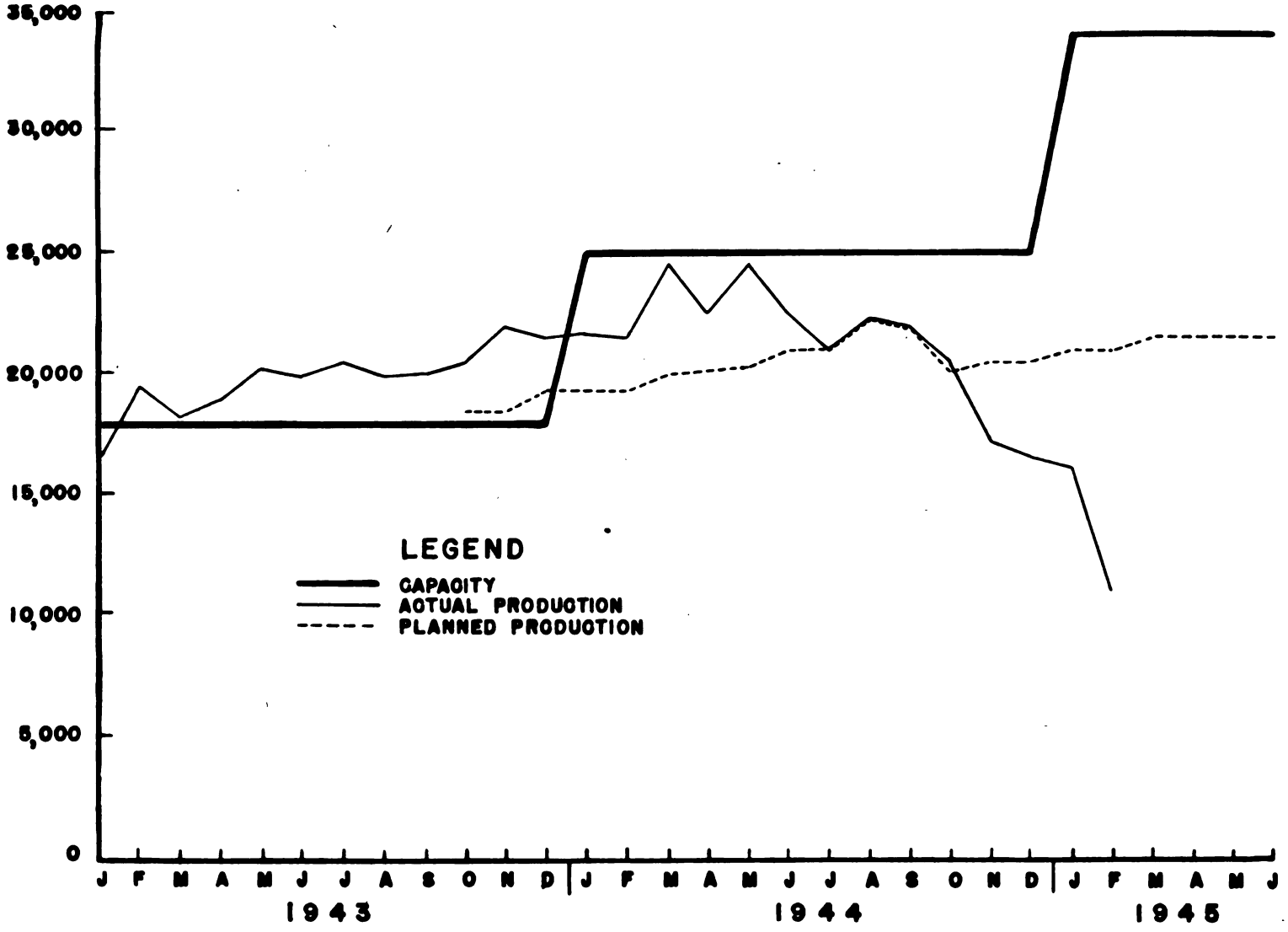

FIGURE III

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Table 2

GERMAN HIGH EXPLOSIVES PRODUCTION

in 1,000 metric tons

Period	Explosives					
	Trinitro toluene	Pentaerythritol tetranitrate	Hexogen	Picric acid	Hexanitro diphenylamine	Total
1939 av/mo	5.59	0.125	0.09	0.125	0.17	6.
1940 av/mo	7.25	0.292	0.292	0.175	0.25	8.25
1941 av/mo	10.56	0.407	0.417	0.25	0.33	11.9
1942 av/mo	11.00	0.605	1.0	0.383	0.42	13.7
1943 Jan	14.2	0.5	1.9	0.3		16.9
Feb	14.3	0.6	2.4	0.3		17.6
Mar	16.9	0.8	2.4	0.3		20.4
Apr	15.3	0.8	2.1	0.3		18.5
May	16.8	1.0	2.4	0.3		18.5
June	17.0	0.8	2.5	0.3		20.6
July	16.2	0.8	2.6	0.4		20.0
Aug	15.5	0.8	2.4	0.3		19.0
Sept	15 .9	0.9	2.3	0.3		19.4
Oct	17.1	0.9	2.5	0.3		20.8
Nov	18.0	1.0	2.7	0.3		22.0
Dec	17.0	0.7	2.5	0.3		20.5
1943 av/mo	16.2	0.8	2.4	0.3	0.42	20.1
1944 Jan	17.7	1.0	2.9	0.3		21.9
Feb	18.4	1.0	3.3	0.4		23.1
Mar	20.8	0.9	3.6	0.4		25.7
Apr	20.6	0.8	2.7	0.4		24.5
May	22.3	1.0	2.1	0.4		25.8
June	21.5	1.0	2.7	0.4		25.6
July	20.4	0.9	2.5	0.4		24.2
Aug	16.4	0.9	2.3	0.3		19.9
Sept	12.1	0.8	2.1	0.2		15.2
Oct	11.4	1.2	2.1	0.3		15.0
Nov	12.6	0.9	1.4	0.4		15.3
Dec	13.1	0.8	1.3	0.2		15.4
1944 av/mo	17.3	0.9	2.4	0.3	0.375	20.9
1945 Jan	10.2	0.6	0.7	0.3		11.8
Feb	7.6	0.6	0.2	0.2		8.6

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Table 3

GERMAN POWDER PRODUCTION

in 1,000 metric tons

Period	Powders				
	Nitrocellulose for powders	Nitro-cellulose	POL	Black, etc.	Total
1939 av/mo					4.4
1940 av/mo					6.25
1941 av/mo					9.35
1942 av/mo					11.5
1943 Jan	10.1	2.1	13.9	0.7	16.7
Feb	12.6	3.2	15.7	0.6	19.5
Mar	13.5	2.3	15.4	0.6	18.3
Apr	13.2	2.4	16.1	0.4	18.9
May	14.2	2.4	17.5	0.4	20.3
June	13.7	2.5	17.0	0.3	19.8
July	14.1	2.5	17.8	0.3	20.6
Aug	13.9	2.5	17.0	0.4	19.9
Sept	13.8	2.4	17.1	0.5	20.0
Oct	13.8	2.7	17.5	0.3	20.5
Nov	14.8	3.4	18.3	0.4	22.1
Dec	14.1	3.4	17.9	0.3	21.6
1943 av/mo	13.5	2.6	16.8	0.4	19.8
1944 Jan	15.7	3.1	18.4	0.2	21.7
Feb	15.4	3.3	18.0	0.3	21.6
Mar	16.3	4.1	20.3	0.3	24.7
Apr	15.6	3.8	18.5	0.2	22.5
May	16.8	3.8	20.7	0.2	21.1
June	15.0	3.0	19.3	0.2	24.7
July	14.0	3.1	17.8	0.2	22.5
Aug.	14.2	3.4	18.7	0.3	22.4
Sept	13.6	3.2	18.5	0.4	22.1
Oct	12.3	3.5	16.7	0.4	20.6
Nov	11.3	3.2	13.5	0.5	17.2
Dec	11.6	2.9	13.1	0.6	16.6
1944 av/mo	14.3	3.4	17.8	0.3	21.5
1945 Jan	9.1	3.1	12.6	0.5	16.2
Feb	5.4	2.6	8.0	0.4	11.0

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finally reduced the ammonia supply to a point where, in the autumn of 1944, there was insufficient nitrogen for war purposes. Those explosives which were relatively wasteful of chemical raw materials were eliminated. For example, the production of hexogen, a very effective and desirable explosive, was first limited in volume and finally dropped in early 1945 because it was felt that more effective use could be made of ammonia and methanol in the manufacture of TNT. Further reduction and complete cancellation of the fertilizer allocation of ammonia was unable to check the trend. Recovery of ammonia from by-product ammonium sulphate stocks was resorted to without success.

e. In frantic efforts to stretch the failing supply of high explosives the following measures were taken: (1) scrap TNT was recovered from obsolete munitions, duds, shell fragments and even floor sweepings; (2) fertilizer stocks were robbed of 10,000-14,000 tons of sodium nitrate, 25,000 tons of kalkammonsaltpeter (a mixture of 60 per cent ammonium nitrate and 40 per cent calcium carbonate) and of German and Italian calcium nitrate in the amounts of 5,000 and 20,000 tons, respectively, for direct use as extenders for high explosives; (3) owing to the sharp decline in methanol production, methanol stocks and reserve stocks of hexamine were drawn upon and consumed in hexogen production in the late summer and fall of 1944; (4) owing to toluene shortages xylenes were nitrated and used as explosives (up to 10 per cent xylene was added to toluene for nitration); (5) picric acid production was increased; (6) aluminum and zinc powders were compounded with ammonium nitrate and other nitrogen compounds as explosives; and (7) pentaerythritol was added without nitration as a carbon carrier. Even these measures were insufficient to permit the filling of all available munitions, so inert diluents, mainly rock salt, were used in increasing quantities from September onward. Fillings were designed with cavities effect, in order to make further savings in explosives and to offset in part the lower energy of the diluted mixture. Despite the extreme measures taken to make more efficient use of nitrogen compounds and methanol, a steady decline in high explosives production occurred, ending with reported figures for February 1945 of 8,500 tons per month.

f. Although there were frequent local shortages of empty shells and other metal components, due mainly to transportation difficulties, the fact that such large quantities of inert extenders were used indicated that the general shortage of explosives was more serious than that of steel components. Large quantities of unfilled shells remained at the end of the war.

g. One important effect of nitrogen shortages not shown by overall production figures was the handicap imposed on flak ammunition production. Due to the lack of aviation gasoline following air attacks

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Table 4

LOSS OF EXPLOSIVES AND POWDER PRODUCTION DUE TO BOMBING OF PLANTS

Plant	Date of Raid	Production ----------tons per month----------	Production Loss ----------tons per month----------
Schoenebeck	21 Jan 1944	1,000 (exp)	500
Clausthal	7 Oct 1944	3,000 (exp)	3,000
Troisdorf	28 Dec 1944	24 (exp)	7
Krummel	7 Apr 1945	3,700 (exp)	3,700
Buneberg	7 Apr 1945	3,000 (pow)	3,000
Wolfratshausen	9 Apr 1945	600 (exp)	8
Kraiburg	11 Apr 1945	1,800 (pow)	1,800

Table 5

FRAGMENTATION OF EXPLOSIVE MIXTURES

Explosive mixture	Fragmentation Exhibit Q	Fragmentation According to Sarrazin
100% TNT	40 m	41 m
60/40 TNT/NH_4NO_3 (ammonium nitrate)	38	39
50/50 "	35	-
30/70 "	34	-
60/40 TNT/NaCl (rock salt)	32.3	28
50/50 "	26.3	-
40/60 "	-	25

Fragmentation is defined as that distance in meters to which a target of one square meter, mounted on a block two meters high, must be moved away from a standard explosive test bomb in order for only one bomb fragment to pierce the target.

Table 6

28 February 1945

PRODUCTION LOST OR ENDANGERED BY CAPTURE
(tons per month)

	a	b	c	a100	b100
	Lost	Endangered	Average industry production 1944	c %	c %
Explosives	2,900	1,575	23,100	12.5	6.7
Powder	4,100	2,100	21,100	19.4	9.9

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on hydrogenation plants, the Luftwaffe's defensive fighting operations were very much restricted and its pilots were at a further disadvantage because of inadequate training. It was then recognized that anti-aircraft artillery would have to carry the main burden of defense against Allied bombers. The program of expansion of flak-gun production was already well advanced. In August 1944, Goering made a plea for an increase in production of powder and explosives, particularly the nitroquanidine powder required for high altitude flak. Although flak munitions were given high priority, the planned production was never approached.

h. Air raids on the high explosives industry before February 1945 had no effect whatever on the ability of the Germans, from a plant capacity standpoint, to meet their explosive requirements (Exhibit N). There was enough unused capacity to absorb the mild shock of the earlier bombing. This capacity avoided the necessity of relocation or dispersal. The Germans made the error, however, of not providing a sufficient chemical raw material cushion in the form of reserve stocks or dispersed production capacity to guard against bombing losses. Thus the large munitions capacity was partially ineffective. On 7 October 1944 the Clausthal plant, which had a monthly production of 3,000 tons of TNT, was destroyed. In December 1944 the Troisdorf plant was hit and 24 tons per month of Nitropenta production were eliminated. This 3,024 tons per month capacity, taken from a total of 27,000 tons per month, left a capacity for 24,976 tons per month. During this period, the production was only about 15,500 tons per month. Most of the effective bombing of the explosive plants took place during the last six weeks of the war, and had no influence whatever on the course or the ending of the war. The Germans were already so short of nitrogen that the plants were out of the war. Table IV summarizes the attacks on powder and high explosive plants.

i. Chart III - Explosive Type Extenders (Ammonium Nitrate). By far the most important explosive-type extender used by the Germans was ammonium nitrate. Figure II shows the relationship between capacity, planned production and actual production. For some reason, the facilities were much greater than pro duction required. It is believed that shortages of toluene, benzene, methanol and formaldehyde indicated to the Germans the need for the increased use of extenders with their high explosives. The plants were built and would have been more fully utilized had the war lasted longer.

j. According to German test data, and to testimony given by Dr Sarrazin, the use of ammonium nitrate did not seriously affect the fragmentation of the explosive charge, as shown in Table V and Exhibit O.

k. The mixtures containing rock salt are shown in Table V because, following the loss of ammonia production in mid-year 1944, the

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Germans were forced to extend their explosives mixtures with non-explosive fillers, the principal one of which was rock salt. The extent of this substitution is shown in Figure 1 in the area designated as inert extenders. Some shells were filled with mixtures of 70 per cent rock salt and 30 per cent explosives. The depreciation in the fragmentation effectiveness of the shell is shown strikingly by the data in Table V. Rock salt was apparently selected because its density was approximately that of the normal charge, and the resulting change of ballistics was not sufficient to require change in range tables.

l. Figure III - Powders. As far as powder production was concerned the Germans experienced a situation similar to the one applying to high explosives, except that powder production in 1943 exceeded the designed capacity reported for that year. The same shortages of ammonia as were operative in the explosives production debacle in late 1944 were operative here. Figure IV shows that an unrealistic production forecast was made, which planned throughout late 1944 and 1945 a level which proved impossible to maintain.

m. At the end of February 1945 a German report was made concerning the explosives and powder production that had been lost or endangered by capture. Table VI summarizes that part of the report dealing with these two classes of war material.

n. Prior to 1944 stocks of mining explosives adequate for four to six months were maintained. With increasing military demands these mining stocks were used up. It was reported that coal production was decreased thereby. Thus shortage of explosives caused a shortage of coal which in turn contributed to the shortage of explosives. This cycle was difficult to overcome.

o. Because of the simplicity of many of the operations and the dangerous nature of some, many foreign workers were employed in explosives and powder plants. This slave labor amounted to 50-60 per cent toward the end of the war; according to Dr. Heinrich Diekmann, of Gebechem, There were always skilled German technicians in charge of most of the production operations. After the campaigns of 1940-1941 oil production had higher priority than explosives and powder and drew workers from these industries.

6. German Production of Some Explosives Raw Materials

a. A review of the experiences of some of the PSV raw material industries during the combined bomber offensive will help to establish the reasons for the inevitable debacle of the last half of 1944 in the German munitions production program. The indirect effects of these attacks on the sources of raw materials far exceeded the effects of direct attacks on the powder and explosives plants.

b. Because of their close relationship to one another and their

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wider chemical applicability ammonia and methanol are treated in another report, but each is related in a most fundamental way to the PSV program. The reader is therefore invited to study that report as part of the subject. There follow brief reviews relating to toluene Hoko (highly concentrated nitric acid.)

c. The PSV program contemplated a total output of 21,500 tons per month of toluene, with early 1945 expansions at three plants bringing the expected total to 15,500 tons. Reliance for 8,500 of the 12,500 tons was placed on the coking industry and 4,000 tons were to be made synthetically from benzene and methanol.

d. In a report dated 6 October 1944 a review of the situation on 1 September 1944 presented to the Germans the picture in the following words: "The situation is such at present that only 7,000 tons per month of cokery toluene is produced. The Waldenburg synthesis had to be reduced to 1,000 tons per month due to shortage of methanol..." A later report, giving the conditions at 1 March 1945 states: "From the quantities of toluene to have been derived from coking plants, amounting to about 8,500 tons per month, 6,700 tons per month are no longer available because of events in the west; furthermore, the 300 tons per month imports from the western countries have been stopped. The Waldenburg plant had to be reduced to 2,000 tons per month due to lack of benzene and methanol. Out of a total capacity for 12,500 tons per month about 9,000 tons per month have been lost. At present capacities amount to 28 per cent." Attention is drawn to the mention of shortages of methanol in each of the above quoted reports. As already explained in this report, methanol and ammonia were made in the same plants and operations alternated between the two according to requirements. The loss of toluene production is shown from data obtained from the Germans and is tabulated below.

e. The immediate effect of the bombing of the facilities for methanol-ammonia production, incidental to the destruction of synthetic oil plants, can be seen by comparing the figures for synthetic toluene production in May and June 1944. Damages to transportation accounted in substantial measure for the reduced production of coke oven toluene during the latter half of the year. The coke oven operations were also interfered with by each Allied plane which flew over them, because operations were brought practically to a standstill in order to avoid revealing the identity of the plant when charges of coke were dumped.

f. Figure V is a copy of the toluene production and capacity chart included in the 1 September 1944 report on the then current progress of the PSV program, and covers the period of the combined bomber offensive. There are a few discrepancies between the data in Table 7 and Figure V from 1 May 1944 onward. No solution of these differences is possible at present. From 12 May 1944 the degree of confusion caused

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GERMAN TOLUENE
PRODUCTION AND PLANNED CAPACITIES IN METRIC TONS

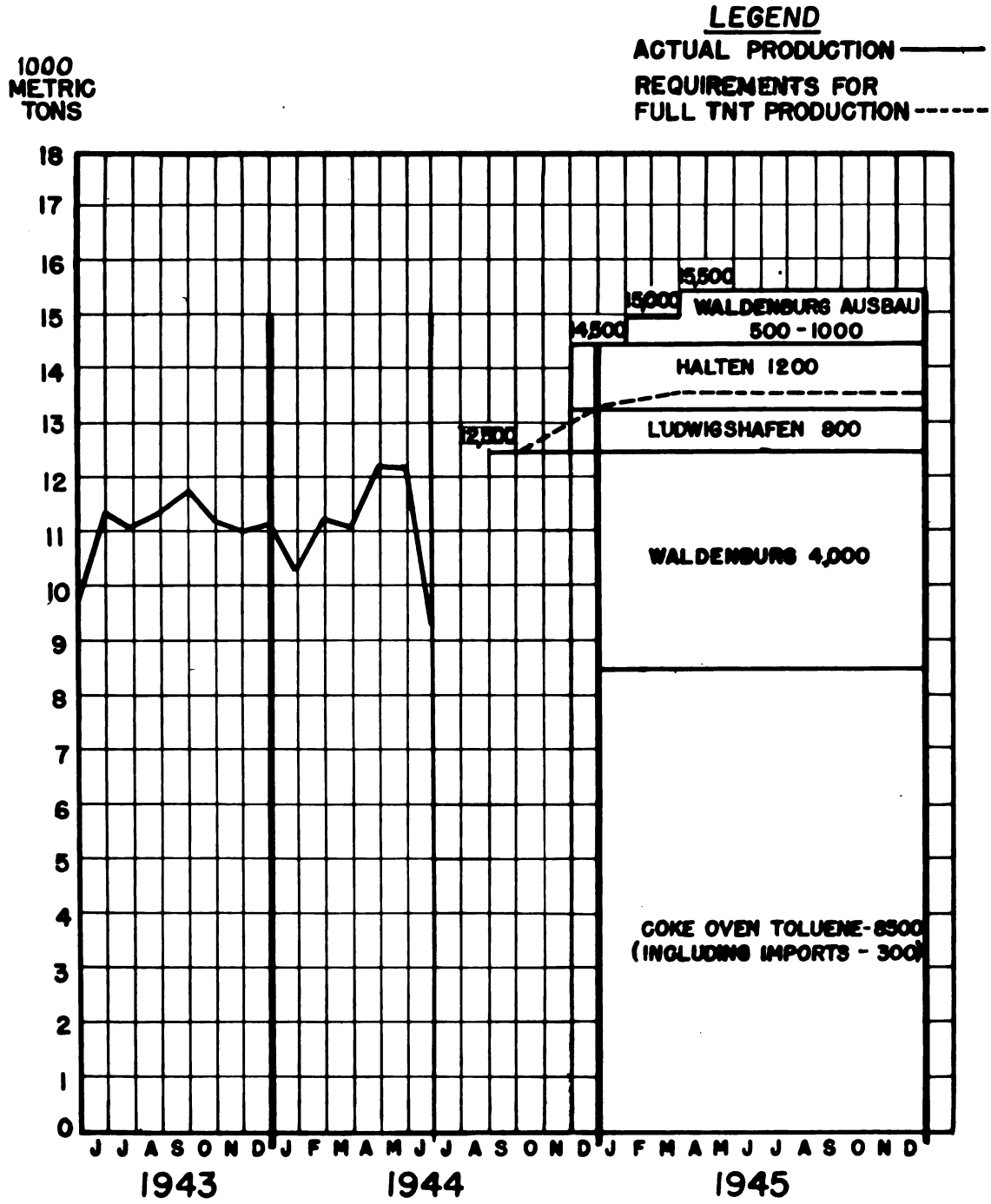

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FIG. V

Table 7.

TOLUENE PRODUCTION IN METRIC TONS

		Coke oven	Synthetic	Total
1943	(total)	83,062		
1944	Jan	7,933	3,267	11,200
	Feb	7,334	3,066	10,400
	Mar	6,991	4,309	11,300
	Apr	7,695	3,505	11,200
	May	8,403	3,897	12,300
	June	8,283	1,717	10,000
	July	6,948	1,152	8,100
	Aug	6,611	1,989	8,600
	Sept	5,646	3,254	8,900
	Oct	5,056	2,444	7,500
	Nov	4,037		
	Dec	2,556		
	Add'nl	3,661		
1944	(total)	81,154		
1945	Jan	2,101		

Table 8. PSV-HOKO - NITRIC ACID

PLANNED AND ACTUAL PRODUCTION IN METRIC TONS PER MONTH

		Planned			Actual
		From NH_3	Imports and recovered acid	Total	Total
1943	July				69,800
	Aug				65,300
	Sept				63,300
	Oct	65,500	16,500	82,000	69,900
	Nov				69,700
	Dec				75,900
1944	Jan				76,000
	Feb				75,500
	Mar				82,200
	Apr				76,500
	May				71,700
	June	55,700	15,900	71,600	71,100
	July	61,600	15,800	77,400	67,400
	Aug	61,200	16,600	77,800	62,000
	Sept	63,900	16,800	80,700	60,000
	Oct	66,000	16,800	82,800	59,100
	Nov	66,400	16,800	83,200	46,000
	Dec	66,600	16,800	83,400	50,000
1945	Jan	66,700	17,700	84,400	25,900
	Feb	61,800	16,300	78,100	11,000

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by air raids was probably such as to prevent actual verification of figures in some cases.

g. The PSV program called for the production of 80,000-85,000 tons of Hoko acid per month during the latter part of 1944. This quantity was to have been increased to about 112,000 tons by early 1946.

h. Complete data are not available to cover the entire period of the combined bomber offensive but there are sufficient data to correlate the heavy raids on the chemical industry, beginning in May 1944, with production of Hoko acid for part of the remainder of the war.

i. Table 8 presents available data and covers the PSV requirements only. For special or other uses 400, 1,000 and 4,000 tons production was planned for the four quarters respectively of the year 1944.

j. Plants operating in 1944 for the oxidation of ammonia to nitric acid had a capacity of 65,000 tons per month and, as long as ammonia was available, production was near the capacity figures. By 1 September 1944, air-raid damage to ammonia plants reduced the output of Hoko acid from ammonia to 57,000 tons. While available imports varied in quantity and quality most Hoko from this source was shut off by 1 September 1944. The quantity recovered from dilute and waste acid amounted to 4,000 - 2,000 tons per month. Plans were made to increase this recovery output, but lack of corrosion-resistant materials prevented materialization of the plans before the end of the war.

k. Figure VI shows the actual production of Hoko from the time the combined bomber offensive began until June 1944. The various plant capacities are indicated and the dotted line shows the anticipated requirements of the PSV program (without rockets) for late 1944 and for 1945.

l. A brief background picture of Hoko acid production is given in Table 9, which is a translated copy of a table in one of the Speer Ministry reports. It gives the quarterly average production of Hoko acid beginning with 1938, and indicates the distribution of the acid between military and industrial uses. Figure VII presents the same data graphically.

m. As already mentioned in this section, manufacture of those explosives which were relatively wasteful of chemical raw materials was abandoned toward the end of the war. It is interesting to note the planned use of Hoko acid in explosives and powder manufacture, had its supply not been curtailed. Table 10 shows the anticipated average monthly production of individual explosives and powders and the corresponding Hoko acid requirements. Only totals for powders are shown. Special and civilian uses of Hoko are also included in the Hoko acid

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HOKOACID PRODUCTION AND USE

(QUARTERLY AVERAGES)

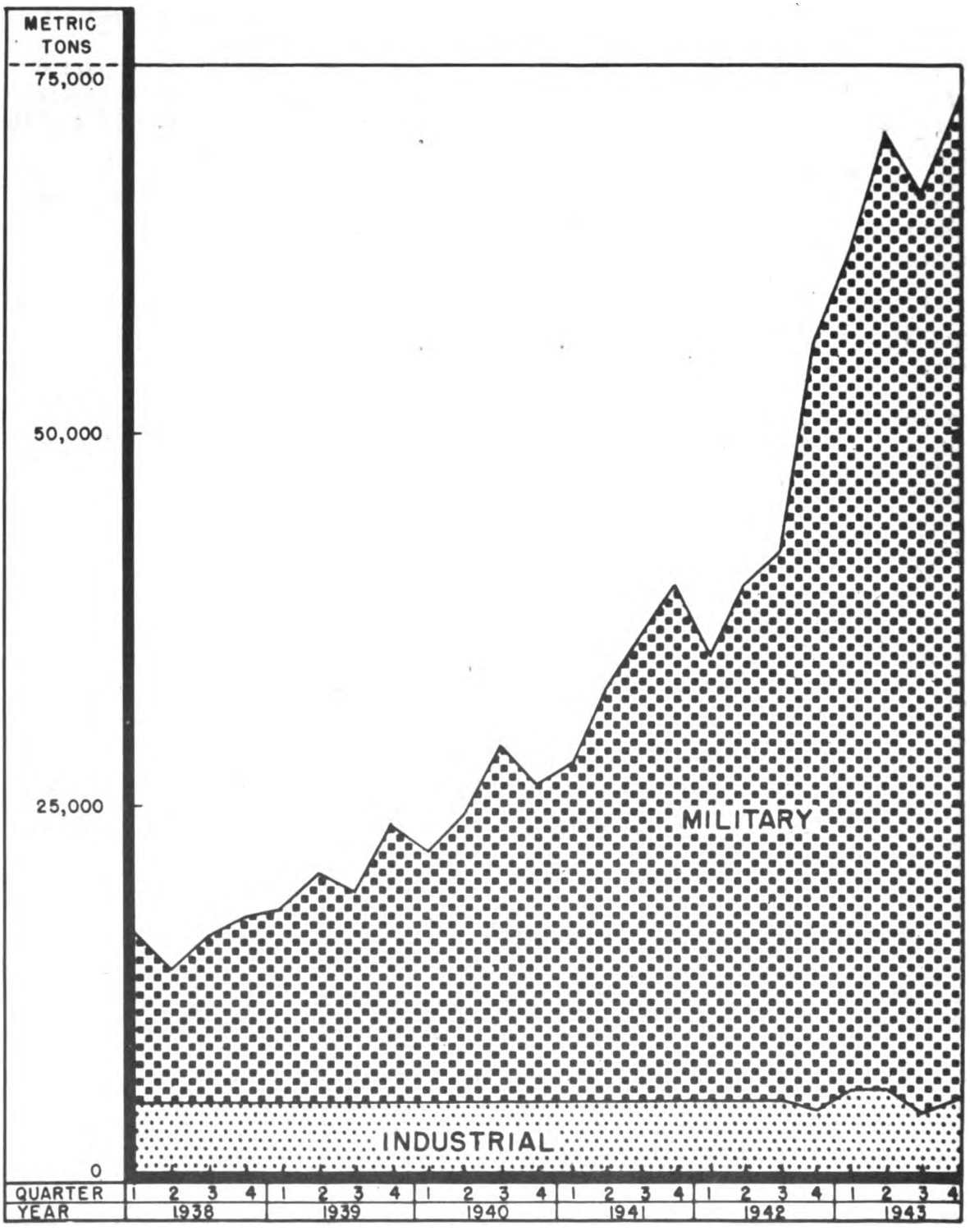

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FIGURE VI

POWDER, EXPLOSIVES AND RELATED PRODUCTS

Table 9.

HOKOSAURE
(tons per month)

Berlin,
3 March 1944

		Production	Military use	Industrial use
1938	I	15,900	10,900	5,000
	II	13,000	8,000	5,000
	III	15,500	10,500	5,000
	IV	17,000	12,000	5,000
1939	I	17,600	12,600	5,000
	II	19,600	14,600	5,000
	III	18,100	13,100	5,000
	IV	23,300	18,300	5,000
1940	I	21,000	16,000	5,000
	II	24,000	19,000	5,000
	III	29,000	24,000	5,000
	IV	26,500	21,500	5,000
1941	I	28,000	23,000	5,000
	II	33,500	28,500	5,000
	III	36,500	31,500	5,000
	IV	39,300	34,300	5,000
1942	I	35,300	30,300	5,000
	II	39,300	34,300	5,000
	III	41,800	36,800	5,000
	IV	56,500	51,800	4,700
1943	I	62,000	56,650	5,350
	II	70,000	64,750	5,250
	III	66,000	61,050	4,950
	IV	72,000	66,900	5,100

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

Table 10.

PLANNED ALLOCATION OF HOKO ACID
WITHIN EXPLOSIVES AND POWDER INDUSTRIES
AVERAGE MONTHLY REQUIREMENTS BY QUARTERS
FIGURES IN METRIC TONS

Quarter:	II/44		III/44		IV/44		I/45		II/45	
Explosives	**Product**	**Hoko**	**Product**	**Hoko**	**Product**	**Hoko**	**Product**	**Hoko**	**Product**	**Hoko**
Trinitrotoluene	22,000	24,200	24,000	26,400	24,500	27,000	25,000	27,500	26,000	28,600
Hexogen	3,500	24,500	4,000	28,000	5,000	35,000	6,000	42,000	7,000	49,000
Picric Acid	300	300	300	300	300	300	300	300	300	300
Pentaerithritol Tetranitrate	800	1,200	1,000	1,500	1,200	1,800	1,200	1,800	1,500	2,250
Special uses		1,000		1,000		1,000		1,000		1,000
Civilian uses		5,000		5,000		5,000		5,000		5,000
Powder										
Nitrocellulose (German)	3,300)		4,000)		4,000)		4,000)		5,000)	
Nitrocellulose (French)	1,200)		2,000)		2,000)		2,000)		2,000)	
Mixed		30,500	500)	33,600	1,500)	35,100	2,000)	36,400	3,000)	29,000
Pol	19,500)	- -	19,500)		19,500)		20,000)		20,000)	
Total acid		86,700		95,800		105,200		114,000		115,150
Recovered acid		18,550		21,200		26,500		31,800		37,100
New acid		68,150		74,600		78,700		82,200		88,050

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figures. The importance attached to hexogen as an explosive can be realized by comparing the Hoko acid requirements for hexogen with those of TNT. Although it required just over one ton of Hoko acid to produce one ton of TNT, seven tons of acid were needed to make one ton of Hexogen.

n. Diglycol, used in preparation of diglycol dinitrate, a nitro-cellulose plasticizing explosive similar to nitroglycerine, was an important war material. Its production curve is shown in Figure VII which also indicates the capacity and the planned capacity increases at the various plants. There was a drop in production in 1943 as a result of the air attack on the synthetic rubber plant at Huels. In December 1943 the Germans decided to take over for erection in Germany a diglycol plant which was being fabricated for Italy.

o. By September 1944 the 450 tons per month production at Ludwigshafen had been lost. Construction of 500 tons per month additional capacity was never completed at that plant. Auschwitz produced for only a short time; Schkopau operated only intermittently, and on 1 March 1945 it was reported that the Germans had lost 48 per cent of their original diglycol capacity.

p. Germany, so far as is known, produced no important quantities of nitroglycerine for war purposes during the last years of the war. In early 1944, 100 tons per month of glycerin out of a total production of about 400 tons was allocated to powder productions as follows:

DAG	16 tons
WASAG Reinsdorf	18 tons
Sprenchein Kleitz	41 tons
Kraiburg	8 tons
Oderberg	4 tons
Semtin	13 tons
	100 tons

q. The Germans had a planned capacity of nitrocellulose for the explosives and powder industry of about 19,000 tons per month. New construction was expected to raise this capacity to 21,700 tons per month early in 1945. None of this new construction was completed and 1 March 1945, plants at Hohensaatem (1,850 tons per month), Bromberg (900 tons per month) and the Christianstadt (1,400 tons per month) had been eliminated. The troisdorf plant, although not captured, had lost 770 tons per month capacity. The Germans had thus lost 26 per cent of their nitro-cellulose capacity. Only four per cent was lost due directly to bombing of the nitro-cellulose plants.

r. The actual production never exceeded, even during the last two years of the war, 16,800 tons per month, the figure for May 1944. Thereafter, production gradually sagged, reaching 5,400 tons in February

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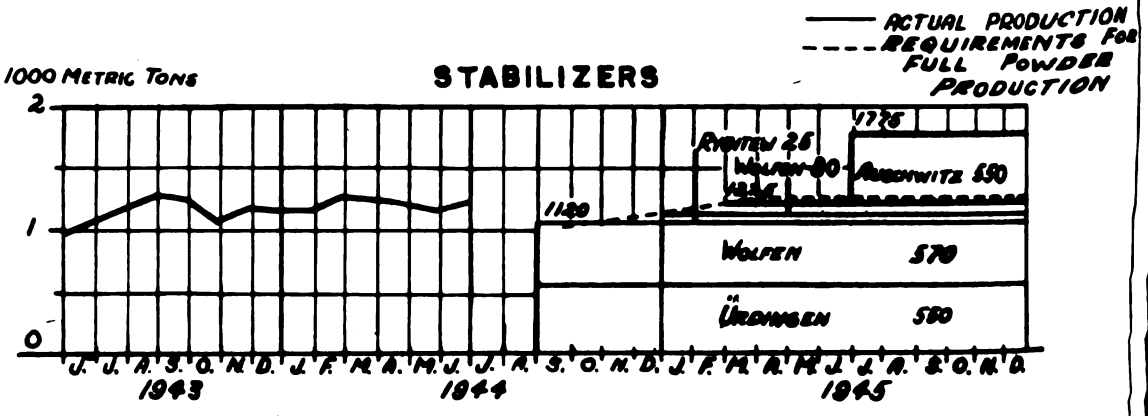
GERMAN PRODUCTION
OF
STABILIZERS AND DIGLYCOL
IN METRIC TONS



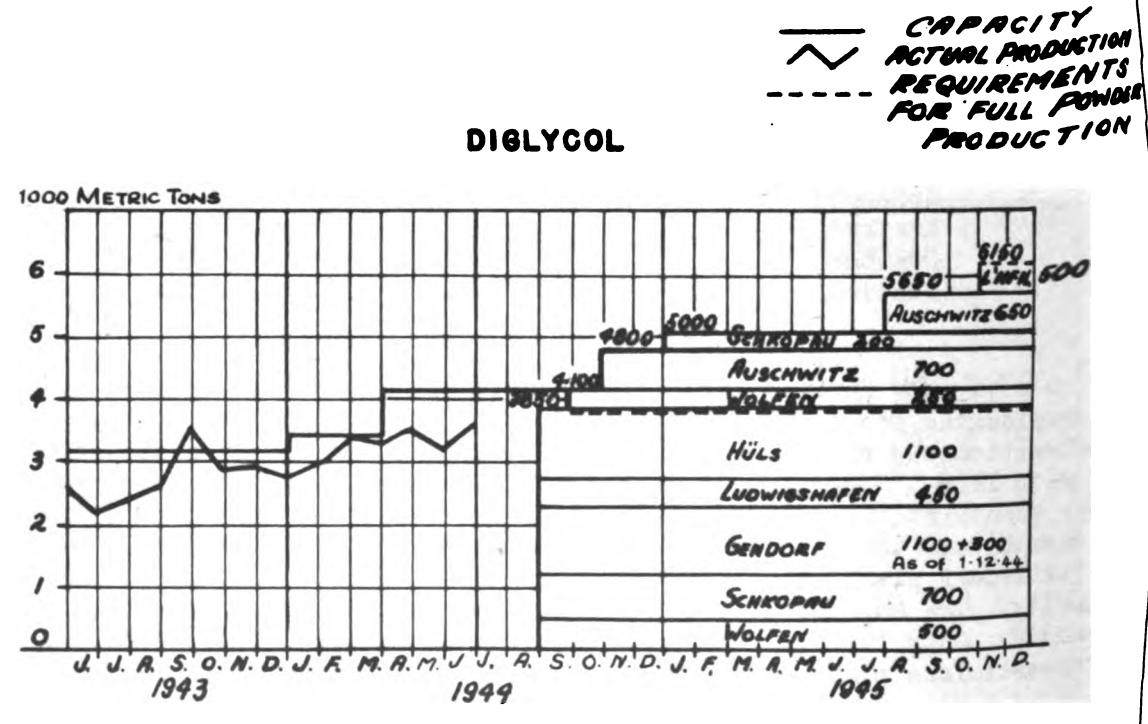


FIG. XI

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Table 12.

Plant	Date of Attack	Air force	No & Type of plane	No of bombs	Size weight	Fuse Nose	Fuse Tail	Area & "Built in UP" acres	Area & "Built in UP" factor	Tons of bombs dropped HE	Tons of bombs dropped IB	Tons of bombs in plant area	Tons per acre in area	No of bldgs	Remarks
Triosdorf plant D.A.G. Troisdorf	27 Dec 29 Dec 1944	AAF RAF	11 B-17 176	168	250GP	.1	.025	380	15	699	7.2	100	.26	192	Spillover from other target
				12	4,000HE	inst									
				65	2,000HE	inst									
				54	1,000HE										
				214	500MC	.1	.025								
				1,836	500MC	.1	.025								
				198	500US	.1	.025								
Deutsche Sprengchemie Kraiburg	11 Apr 45	8th AF	133 B-17	1,520	500GP	.1	.01	650	8	381	0	?	?	507	No bomb plot available
Duneberg plant of D.A.G. Duneberg (Hamburg)	7 Apr 45	8th AF	168 B-24	52	1,000HE	4-5	.025	970	10	445	.5	219	.226	652	
				1,710	500HE	4-5	.01								
				9	100IB										
Krummel plant	7 Apr 45	8th AF	127 B-24	974	500RDXGP	.1	.025	794	10	345	.5	163.75	.207	790	
				216	500RDXGP	.01	.25								
				50	1,000RDXGP	.1	.01								
				10	100IB										
Clausthal-Zellerfeld plant of D.A.G.	7 Oct 44	8th AF	129 B-24	338	1,000GP	.1	.025	750	7	346	0	95.75	.127	214	
				3	500GP	.1	.025								
				145	300GP	.1	.025								
				1,401	250GP	inst	.025								
Schoenbeck, Lignose Sprengwerke	24 Jan 44	RAF	2 Halif	2	2,000HE	Unknown		125	30	2	4.3	?	?	309	No bomb plot available
				1,748	120XIB										

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1945. The production record is shown in Table 3. Figure 4 shows graphically the production through late 1943 and early 1944, together with the amount required to fulfil the PSV program. The capacities of the several plants are shown along one side of the Figure.

s. Despite their importance, stabilizers were manufactured in only two plants in Germany. This fact indicates that these two plants would have been exceptional strategic targets. Construction of two small additional plants, one at Wolfen and one at Urdingen was under way and production was to have begun early in 1945. This would have added 104 tons per month to a capacity of 1,120 tons per month already on hand. Production actually proceeded on an average level of about 1,100 tons per month June 1943 to June 1944, which was just enough to satisfy the requirements of the powder plants. In September 1944 the Russians were getting close the site of another new plant at Auschwitz. In consequence the Germans considered the desirability of building a similar sized plant in the center of the Reich. By 1 March 1945 both Auschwitz and Rybiteq had fallen and air attacks had stopped the production at Urdingen, leaving the Wolfen plant the only one in operation. This production of 570 tons per month production was only 51 per cent the previous output. Figure 7 shows the production from the start of the combined bomber offensive until the end of June 1944. No production figures are available for later months.

t. There was disagreement regarding stocks of stabilizers. Dr Diekmann of Gebechem stated that there were no stocks after 1944. Gunther Wolff of Wolff and Company claimed, in a written statement dated 5 July 1945, that even if the plants at Urdingen and Wolfen had been knocked out, the supply would have lasted a year.

7. Summary of Bombing Attacks on the Industry

a. The German general staff realized the vital importance of the powder and explosives industry in Germany's ability to wage war, and fully anticipated bombing attacks on the plants. Accordingly certain defense measures were included in the construction plans. Protective measures in anticipation of intensive bombing were of two classes, passive and active. Both proved ineffective. The first passive measure was to plan and construct a large excess capacity in plants well dispersed over the country. With regard to the plants themselves, the buildings were separated from each other and were arranged in irregular patterns. They were usually located in forests, which provided natural camouflage. This however, might have proved to be an additional hazard in the form of forest fires had the raids been conducted in dry season with incendiary bombs.

b. Buildings were provided with reinforced concrete roofs covered with soil. Buildings were surrounded by blast walls of a reinforced concrete core six to seven feet thick with an earth abutment of

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12 to 15 feet on each side of the core. In most cases the height of the blast wall equalled that of the building. The walls were pierced for passages. These passages and portals were also made of reinforced concrete of about the same thickness. In many instances corridors in the walls served as shelters in case of an explosion.

c. Fragment protection walls of reinforced concrete, sand bags, etc, were provided for the centralpower plant, working rooms and important equipment. Air raid shelters of reinforced concrete were also provided. The above types of protection against fragments were considered effective. Good blackout control and decentralized fire fighting equipment were provided. Smoke screens were not used because of the shortages of chlorosulphonic acid for smoke production and also because of the German faith in natural camouflage. Balloons were tried on a few of the bottleneck plants at first but were abandoned later. No decoy plants were used. According to Dr Sarrazin the active measures consisted entirely of light and heavy flak. The light flak proved useless. Heavy flak was not favored because of possible destruction by falling fragments. Apparently insufficient priority was given these plants to obtain fighter protection. None of the plants surveyed had any flak or smoke screen protection. Neither was there any fighter opposition.

d. The Germans did not disperse TNT units as we do in the United States. Usually they concentrated several of volume capacity under one roof and had only two lines of production. Damage to one line reduced production 50 per cent. In such plants TNT areas should have been aiming points.

e. The German powder and explosives industry was never selected for intensive strategic bombing. It was not even listed on any of the bombing plans. Towards the end of the war munitions depots were given fourth priority, but neither the sources of powder and explosives, nor the plants producing raw materials, such as chemicals needed for their manufacture, were ever considered with the objective of knocking out the industry.

f. Towards the end of the war, when there were fewer other targets, a few powder and explosives plants were subjected to casual bombing. Apparently no discrimination was used in selecting the targets. For the Duneneberg plant of Dynamit AG and the Krummel plant four miles away from which it obtained its raw cordite paste, were bombed the same day. The destruction of Krummel would have closed the Duneneberg plant because of lack of raw material, so there was actually no necessity for bombing Duneneberg. The load of bombs could have been used on the Wittenberg or Bomlitz plants which were important.

g. Air raids on the high explosives industry before January

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1945 had no effect whatever on the ability of the Germans to meet their high explosive requirements. There was enough unused capacity to absorb the mild shock of the earlier bombings. This capacity avoided the necessity of relocation or dispersal. The Germans made the error, however, of not providing a sufficient cushion to guard against bombing losses in production of raw materials and thus the large munitions capacity was partially ineffective.

h. The plants surveyed by Team 83 of the Oil, Rubber and Chemical Division of the USSBS are listed in the following table:

TABLE 11

LOSS OF EXPLOSIVE AND POWDER PRODUCTION DUE TO BOMBING OF SURVEYED PLANTS

Plant	Date of Raid	Production Tons per Month	Production Loss Tons per Month
Schoenebeck	21 January 1944	1,000 (Explosives)	500
Clausthan	7 October 1944	3,000 "	3,000
Troisdorf	28 December 1944	24 "	7
Krummel	7 April 1945	3,700 "	3,700
Dueneberg	7 April 1945	3,000 (Powders)	3,000
Krailburg	11 April 1945	1,800 "	1,800

i. According to the information received from the Germans the following additional plants not listed by our intelligence service were also bombed.

Allendorf VEE	5,000 tons per month TNT. Some damage by spill-over from attacks on adjacent rail yards.
Bobingen Gmb HVCE	300 tons hexogen and Pol powders (Solventless cordite). Raid in 1943. Damaged.
Doberitz Gmb HVCE	600 tons hexogen, 600 tons hexamine. Slightly damaged by eight explosive bombs late in 1943.
Gusen Gmb HVCE	1,300 tons per month nitrocellulose. 1,200 tons per month TNT. Slightly damaged by low level attack.

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Wolfratshausen	Nitro-Penta 100 tons per month. Primer caps 10,000 per month. Detonating fuses 300,000 per month. Slight damage.

j. Air raid data regarding these plants are not available from intelligence sources and the actual extent of damage is unknown.

k. Table 12 lists the attacks, weight, type of bombs, fuzing and bomb density per acre for the plants surveyed. The data have been obtained from G2 and checked with the data received from the German officials of the plants surveyed.

l. In the part of this report dealing with the bombing of the explosives industry, the data supplied by G2 through the machine tabulating section was disregarded. It was thought to be inaccurate and was incomplete. Of the 22 targets listed by them only six were German explosives, powder or propellant plants. At least 11 were French or Italian plants and Ploesti, Rumania, was included in the list. At least five plants were raided which do not appear in the MTS summary. Therefore, remarks concerning bombing are based entirely on the observations made at plants actually visited.

8. Dueneberg Plant of Dynamite AG which produced propellant powder of various compositions was badly hit. Several secondary explosions resulted; the most spectacular was an explosion of 200 tons of nitroquanidine in bulk storage. The explosion caused the destruction of buildings and installations in a circular area of about 1,700,000 feet in diameter.

a. In one building, containing 60 to 80 tons of rocket powder, a secondary explosion produced a crater almost as large as the one just described and levelled and partially burned all surrounding trees.

b. Secondary explosion of a storage magazine containing 50 tons of powder produced a crater 100 feet in diameter and about 45 feet deep.

c. Only nine 100-lb incendiary bombs were dropped and it was not possible to ascertain what damage they did to the plant and whether the secondary explosion were caused by the high explosives or incendiaries, or both.

9. Krummel Plant of DAG was hit at the same time as the Dueneberg plant. The damage to the entire plant including the equipment was estimated to be about RM 30,000,000 of 15 per cent of the entire plant cost. Although the effect of the bombing was to stop production in all divisions of the plant, other departments could have been repaired in

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comparatively short time with the exception of the nitro-cellulose division.

Nitro-Penta division	needed eight to ten days overhauling to start full production.
Nitro-Penta presses division	could be overhauled in four to six weeks, including the replacement of destroyed cables and power lines.
TNT presses bodies plant	partial production could be restored in 14 days; full production in two months.
Shell loading plant	intact.
Hexogene	repairs four to six weeks to restore full capacity.
Plastics manufacture	full production in all sections six to eight weeks.
TNT plant	5-6,000 working hours for restoration to full capacity.
So_3 plant	50 per cent in three weeks. Full production in five weeks.
Cordite paste	six weeks.
Nitroglycerine plant	three weeks.
Nitro-cellulose plants (2)	15 per cent capacity four to five weeks.
	33 per cent four months.
	70 per cent nine months.
	100 per cent twelve months.

Naturally, because of the lateness of the attacks, the plant was never repaired.

10. Clausthal-Zellerfeld Plant DAG, engaged in the production of TNT and in shell loading, was bombed at a time when the plant was not operating. Seventy buildings out of a total of 214 received direct hits; besides, there were 53 direct hits on the system of underground piping. Only one secondary explosion was recorded, when a small powder magazine was hit. Hits between the buildings and blast walls resulted in heavy destruction because of the damming effects of the narrow space; glancing hits or near hits, while caving the lightly constructed walls, left the heavy equipment, like nitrators, undamaged.

a. Wherever the bombs penetrated concrete roofs and exploded inside, column supports were destroyed and caused the collapse of the roof; this resulted in damage to the equipment. The most severe damage was, however, suffered by the surface and underground piping, especially in the TNT area. These underground lines were buried in the trenches and covered with hard rubble. The damage to this intricate network of pipe-lines was estimated as follows:

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Products mains	100% destruction
Steam mains	70% destruction
Air mains	80% destruction
Warm water mains	80% destruction
Sewage mains	70% destruction

b. It would have required about three months to bring the shell loading plant and acid area to about 50 per cent of the capacity, and about six months for the TNT complex.

c. Schonebeck plant of Lignose Sprengstoff Werke, which produces toluene and industrial explosives, had detonators and fuses hit by two Halifaxes, which dropped two tons of high explosives and 4.3 tons of incendiary bombs. The destruction caused was enormous, due to the secondary explosions caused by fires. As a result of this, the capacity of the TNT plant was reduced approximately 50 per cent. The electric fuse plant recuperated with full capacity within ten months. No attempt was made to repair the TNT plant. This is the only one of the explosive plants surveyed by USSBS where incendiaries in quantity were used. Combined area of TNT division was hit by 4-lb incendiary bombs. A packaging shed, a TNT washhouse, one tri-nitration building, two granulating buildings and a crude TNT drying room (which contained about six tons of TNT) were completely destroyed. A secondary explosion occurred in the recrystalization building, probably caused by the explosion of an alcohol-air mixture. The trinitation building caught fire, setting the dinitro toluene tanks in flames. At the time of the explosion, trinitrators contained about eight tons of TNT. Heavy pieces of equipment were found 900 feet away from the building. A deep crater was found on the site of this building.

d. The built-up factor of this plant is estimated to be 30 per cent and the acreage 125 acres. The density of the pattern of the incendiary bombs alone is therefore .035 tons per acre. We can compare this with 363 tons of HE dropped on Clausthal with 750 acres area, where 95.75 tons of bombs fell in the area giving a density of .127 tons per acre. In other surveyed plants the density of HE bombs was even greater, up to .26 tons per acre, with less results than the incendiaries in Schoenebeck.

11. Kraiburg Plant of Deutsche Sprengchemie produced double base propellants. The destruction caused by the raid was so extensive that production was completely stopped. Although the primary damage inflicted by direct bomb hits was heavy, the greatest damage occurred when secondary explosions took place. In one case, a magazine containing nipolit and 18 to 20 tons of raw powder, was hit and exploded. The crater was 75 to 80 feet in diameter and 20 to 25 feet in depth. The blast was so great that trees were blown down 175 to 200 feet away and dirt was blown from an area of 100 feet in diameter.

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a. The most amazing explosion, however, occurred when a bomb hit a storage tank containing 300 tons of 82 per cent peroxide. The secondary explosion produced a crater 125 feet in diameter and 40 feet deep. The tank was torn apart and thrown in two different directions 100-150 feet away.

b. The destruction caused by the raid was so extensive that production ceased. The date of the raid was such a short time before the end of the war that no repairs or removal of debris had gotten under way.

12. Troisdorf Plant of Dynamit AG, which is one of the largest plants in Europe producing industrial primers, fuzes and detonators, was not a primary target. From the spill-over it received 364 bomb hits, representing 100 tons of bombs on the total plant area of 380 acres. The result was complete destruction of the metal working plant, which made casings for detonators. No attempt to rebuild the plant was made. Damage to the plastics area of the plant was minor. As a result of the fire there was only one case of secondary explosion in the electric fuzes building. One magazine, containing 1,000,000 detonators surrounded by blast walls, received a near hit. The result was that the walls caved in but a sympathetic explosion did not occur.

13. This industry as a whole could have been knocked out successfully even at earlier stages of the war and the loss of its productive capacity would have had a profound effect on the German capacity to continue with the war. On 1 January 1944 accumulated stocks of explosives were estimated to be about 230,000 tons. At the rate of 70,000 tons per month expenditure of explosives by German armed forces during the months after D-day, these stocks would have lasted only three to four months.

14. In order to cripple German ability to wage war it would have been necessary to knock out only seven out of a total of thirty-five powder and explosives plants, namely:

Allendorf	capacity 5,000	tons	per	month	explosives
Bromberg	1,200	"	"	"	"
Clausthal	2,800	"	"	"	"
Hessisch Lichtenau	3,500	"	"	"	"
Krummel	2,800	"	"	"	"
Schlebush	2,300	"	"	"	"
Eisnig	2,600	"	"	"	"

These plants, with a combined capacity of 20,200 tons per month accounted for 70 per cent of the total German Potential of TNT production.

15. The use of selected weapons such as incendiaries and pattern bombing would have reduced the expenditure of effort required to put an

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explosives or powder plant out of commission. A raid on Schoenebeck Plant of Lignose Sprengstoff Werke GmbH, is a good illustration of this point. It required only 4.3 tons of IB and two tons of HE bombs dropped by two Halifax bombers to accomplish a 50 per cent reduction in the TNT capacity of this plant. It took 10 months for recuperation of the electric fuzes division of the plant. The area of the plant was 125 acres, with a built-up factor of 30 per cent. Consequently, the bomb density of incendiaries was .037 tons per acre. Considering that it took hundreds or even thousands of tons dropped on other types of plants to get similar effects, these results were amazing. At Schoenebeck incendiaries started uncontrollable fires, which set secondary explosions so great that there were only holes in the ground where buildings had stood.

16. In the raids on explosives plants, the aim should be to start the fires, take steps to prevent the enemy from attempts to put them out and let the secondary explosions finish the job. In every one of the plants surveyed most of the damage was caused by secondary explosions, either from fire or direct hits by HE bombs.

17. The recuperability of powder and explosives plants is of a very low order. Even under the most favorable conditions of materials and labor supply, it takes six to nine months to restore the plant to its original productive capacity.

18. German explosives plants were particulary vulnerable to the attacks by low flying aircraft because they generally lacked any anti-aircraft or fighter protection.

19. Table 13 shows how bombing and capture affected productive capacity was hardly touched by the Allied raids (87.7 per cent of the TNT productive capacity was still operable on 15 February 1945). Powder production capacity was still in the range of 75 per cent, whereas raw materials, rarely a primary target, suffered heavily as the result of Allied plant raids and/or capture of the plants. For instance:

Ammonia	capacity	was	reduced	93.1%
Toluene	"	"	"	72.0%
Methanol	"	"	"	84.5%
Formaldehyde	"	"	"	81.0%
Ammonium Nitrate	"	"	"	53.2%

21. As a result of these losses in the production capacity of raw materials for the explosives and propellants, the remaining capacity of the explosives plants could not be fully utilized. Production of nitro-penta (pentaery-thritoltetra-nitrate), picric acid, and nitro glycerine was abandoned. Trinitro-toluene production on February 28th was only 45 per cent of the capacity, and Pol-powder (solventless

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powder). 75 per cent.

22. Another bottleneck phase of powder manufacture, which would have been an excellent target for strategic bombing, was the manufacture of stabilizers. Practically 100 per cent of the production of these materials was concentrated in two plants.

23. General Effect of Bombing of Explosives Industry on Germany's Ability to Wage War

a. The direct influence of bombing attacks on the explosives industry on allocations of explosives and powders to the several military services was negligible. As the industry was not selected for intensive, high priority bombing, the number of attacks was small and they came late in the way. The capacity for manufacture and filling of powder and explosives was never reduced below the supply of raw materials, nitric acid from ammonia, toluene, methanol, hexamine, pentaerythritol and diethylene glycol.

b. Before the war, Germany had accumulated a fairly large reserve of military powder and explosives on which she could draw supplies for some time even if production had been stopped completely. The size of the reserves is difficult to determine. The British Economic Advisory Board, Ministry of Economic Warfare, estimated a pipeline of 18 months for munitions in 1944 and about 12 months at the beginning of 1945. A letter dated 12 September 1943, found in the Speer Ministry files stated that a reserve supply was available, which would suffuce for 10 months at the highest consumption rate experienced up to that time, even if production were stopped completely.

c. However, no reliable information on stocks of explosives and propellants is available. The data on captured Allied ammunition was lacking. There was no information on stocks lost by the Germans during their retreats. Different German authorities gave widely diverging figures. In one document, for instance, Gebechem gave the stocks of powder on 1 October 1941 as 169,000 tons and another 10,000 tons on 1 October 1940, although the balance of production over consumption for that year was only 65,000 tons. Speer, reporting to Hitler on shortages of powder and explosives, complains that on 1 October 1942 loose powder stocks were enough for four months dnd explosives for only one month.

d. In order to arrive at some idea of the accumulation of stocks Exhibit K3, it was assumed that no great amount of stocks were available on 1 January 1940. Balancing the monthly production and consumption of explosives the figures in Table 14 were arrived at.

e. The destruction of the synthetic methanol and ammonia plants resulting incidentally from the air attacks directed against the

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Table 13.

STATUS OF GERMAN EXPLOSIVES AND RELATED INDUSTRIES ON 15 FEBRUARY 1945

Product	Total capacity 100% (tons/month)	Total loss (tons/month)	Percent of capacity	Temporary loss (tons/month)	Percent of capacity	Operable 15 Feb 45 (tons/month)	Percent of cap
TNT	22,000	1,200	5.0	1,500	7.0	19,300	87.7
Hexogene	2,600	1,700	65.0	-	-	900	35.0
Solventless powder	19,200	3,100	17.0	1,500	8.0	14,600	75.0
Concen Nitric acid	62,500	9,950	15.9	1,600	2.6	50,950	81.5
Oleum	93,000	7,200	7.75	22,625	24.5	63,175	68.0
Methanol	30,575	21,000	68.8	5,000	16.3	4,575	15.5
Toluene	12,500	300	2.4	8,700	69.6	3,500	28.0
Formaldehyde	15,750	1,500	9.5	11,140	70.8	3,110	19.7
Hexamethylene-Tetramine	4,650	2,850	61.5	0	0	1,800	38.7
Pentaerytritol	1,025	0	0	300	29.2	725	70.8
Ethylene oxide	7,100	1,250	17.6	1,250	17.6	4,600	64.8
Diglycol	3,850	700	18.2	1,150	30	2,000	51.8
Stabilisers	1,120	0	0	550	49	570	51.0
Guanidine nitrate	1,950	0	0	0	0	1,950	100.0
Nitro guanidine	1,000	0	0	600	60	400	40.0
Methyl nitrate	1,010	1,000	99.0	0	0	10	1.0
Methylaminenitrate salt	1,000	1,000	100.0	0	0	0	0
Di-Nitro-Anisol	350					350	100.0
Di-Nitro-Benzine	3,450	450	13.2	700	20.6	2,300	66.4
Nitrocellulose	19,000	4,150	21.8	770	4.2	14,080	74.0
Ammon nitrate	30,000	11,000	36.8	5,000	16.7	14,000	46.8
Ammonia as ("N")	71,300	10,200	14.3	56,100	78.8	5,000	6.9

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powder). 75 per cent.

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Concen Nitric acid	62,500	9,950	15.9	1,600	2.6	50,950	81.5
Oleum	93,000	7,200	7.75	22,625	24.5	63,175	68.0
Methanol	30,575	21,000	68.8	5,000	16.3	4,575	15.5
Toluene	12,500	300	2.4	8,700	69.6	3,500	28.0
Formaldehyde	15,750	1,500	9.5	11,140	70.8	3,110	19.7
Hexamethylene-Tetramine	4,650	2,850	61.5	0	0	1,800	38.7
Pentaerytritol	1,025	0	0	300	29.2	725	70.8
Ethylene oxide	7,100	1,250	17.6	1,250	17.6	4,600	64.8
Diglycol	3,850	700	18.2	1,150	30	2,000	51.8
Stabilisers	1,120	0	0	550	49	570	51.0
Guanidine nitrate	1,950	0	0	0	0	1,950	100.0
Nitro guanidine	1,000	0	0	600	60	400	40.0
Methyl nitrate	1,010	1,000	99.0	0	0	10	1.0
Methylaminenitrate salt	1,000	1,000	100.0	0	0	0	0
Di-Nitro-Anisol	350					350	100.0
Di-Nitro-Benzine	3,450	450	13.2	700	20.6	2,300	66.4
Nitrocellulose	19,000	4,150	21.8	770	4.2	14,080	74.0
Ammon nitrate	30,000	11,000	36.8	5,000	16.7	14,000	46.8
Ammonia as ("N")	71,300	10,200	14.3	56,100	78.8	5,000	6.9

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

Table 14.

	Cumulative stocks	Average monthly consumption based on preceding year	Stocks adequate for
1 Jan 1941	98,100 tons	5,870 tons	17 months
1 Jan 1942	163,133 tons	13,746 tons	12 months
1 Jan 1943	197,424 tons	21,370 tons	9 months
1 Jan 1944	227,824 tons	28,800 tons	7 months
1 Jan 1945	98,222 tons	52,000 tons	1.9 months
	Similar calculations for powder will give the following results:		
1 Jan 1941	49,000 tons	2,150 tons	22.7 months
1 Jan 1942	107,900 tons	4,450 tons	28.2 months
1 Jan 1943	165,185 tons	7,550 tons	21.7 tons
1 Jan 1944	253,382 tons	8,350 tons	30.0 months
1 Jan 1945	209,382 tons	17,000 tons	12.3 months

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large hydrogenation plants making aviation gasoline had serious consequences in both the quality and quantity of German explosives and munitions from the middle of 1944 on. The reduction in ammonia production was reflected within two months by a sharp decrease in the nitration grade nitric-acid (hoko) required for the production of most powders and explosives. It was impossible to fill the gap even by cancelling all new allocations of ammonia to agricultural fertilizers and robbing reserve stocks previously accumulated for that purpose. The pure high explosives, such as TNT and hexogen were diluted with the non-explosive extender, rock salt, in addition to sodium nitrate and a mixture of calcium carbonate and ammonium nitrate recovered from weak acid solutions, in order to fill the shells available. While only 40 per cent of rock salt was used initially with a small decrease in fragmentation effect, they were forced to increase the proportion of rock salt from time to time. Evidence was found of the use of as much as 70 per cent with correspondingly poor fragmentation effectiveness in the early months of 1945. Although reports of local shortages of empty shell cases, apparently the result of both shortage of steel and transportation difficulties, increased in frequency throughout 1944, the fact that important volumes of rock salt were used indicates that the general shortage of high explosives was more acute than shortages of metal components.

f. Information from Speer documents and that obtained by interrogation of other officials controlling munition production shows a policy of filling the maximum number of bombs and shells to produce the noise of explosion regardless of the fragmentation and detonation effect on the target.

g. The shortage of methanol imposed additional difficulties on explosives production. The highly brisant explosive hexogen which because of its insensitiveness, was particulary desired for armor piercing shells, had to be abandoned almost entirely because of the high consumption of both methanol and ammonia in its manufacture. It was considered thqt the available methanol could be used more advantageously in the production of TNT and nitropenta which, nevertheless, were limited by methanol shortage.

h. By the air attacks on the carbide and ethylene oxide plants, the production of diethylene glycol dinitrate used in the manufacture of double-base powders was seriously curtailed. This situation was alleviated somewhat by cutting the production of mustard gas, which also required ethylene oxide. Even so, Germans were forced to use more straight nitro-cellulose powder where possible (in small tube, cord, and granule forms). Although the brains of German explosive experts were cudgeled to devise new means of stretching the failing nitric-acid supply, and desperate efforts were made to recover waste acid, waste TNT and high explosives from duds and obsolete ammunition etc., the overall munitions output steadily decreased until, according to General Henrici of the

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army weapons office, the production February 1945 was only about 30 per cent of even that of October 1944.

24. An accurate assessment of the military effects of munitions shortages is difficult because the situation was moving so rapidly in the last months, and was complicated with fuel shortages and transportation difficulties. The Germans were being driven back so rapidly that they lost much of their ammunition stocks by capture. This is shown by the following testimony of Field Marshal Keitel:

a. "Ammunition was short from time to time, especially ammunition for armored vehicle weapons. Of course, that changed from time to time and depended on the quantities that were consumed. These quantities were not always consumed, but very often lost. On the Eastern front, many ammunition dumps were lost during the retreat. That is one thing peculiar to ammunition. You lose it when you retreat because you cannot possibly move it along. During the invasion as well, we had lost large quantities of ammunition, and therefore, the shortages were very changeable. There were other reasons for it, too. For instance, an ammunition plant would be destroyed or heavily hit, and then there would be a shortage for a few weeks. We had never had enough for our tanks and tank destroyer guns, as well as for all our defensive weapons. This was made increasingly difficult with the increased production of gun barrels. If I calculate that I must have 1,000 rounds for every barrel, I will produce 1,000,000 rounds, but if I double the quantity barrels, which happened during the increased production, I have only half of the ammunition needed for one barrel. Another reason was that we had a lot of ammunition tied down in other theaters of operation which we were unable to mobilize immediately; as for instance in the Balkans, Hungary, Rumania, Italy and so on. We had to store in all these places a minimum amount of ammunition which would enable us to fight until more supplies could be brought up, because we were not able to figure on an immediate supply in case those theaters of operation had become more active. The transport took a long time, so that in the north we had to keep an eight week's supply of ammunition. Smoke was also very short. All this increased through sudden losses caused by bombing attacks, which would be equalized only after weeks, in the best case. The consumption did not change."

25. Calculations based upon the best available production figures indicate that Germany had a fair reserve of propellant powders left in the early months of 1945, but had become seriously short of high explosive fillings for bombs and shells. In April 1945, according to General Buhle, an Armament Emergency Program was adopted which comprised the conversions of 105 mm howitzers to 75-mm in order that twice the number of projectiles could be made. Another consequence of explosives shortage was the inability to approach planned production of flak ammunition. According to testimony given by General von Axthelm, General

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of Flak Artillery, and Lt Col Sieber, only about one-third of the necessary flak ammunition was available in the closing months of the war. They attributed this to the bombing of chemical plants and transportation facilities. Col Sieber stated that the bottleneck was in the high explosive filling for the projectiles. In order to conserve and more efficiently use the available ammunition, orders restricting firing were imposed at the beginning of 1945. Flak batteries were to fire only when the installation they were defending was actually attacked. Passing formations were not to be fired on unless they were ideal targets. Barrage fire was forbidden. The Field Artillery, which had a lower priority than the Flak Artillery, suffered even more from lack of ammunition. It was frequently necessary for the flak batteries to fire missions normally fired by the field artillery. Col Gen Jodl confirmed the statement that the worst shortage occurred in ammunition for field artillery.

26. The most serious indirect attacks decreasing production in this industry were the attacks on transportation. They resulted in slowing down the delivery of raw materials, coal, shell casings, nitric acid, nitro-cellulose etc, to such an extent that production in some plants dropped 25 per cent towards the middle of 1944, and in some cases even caused a total interruption of production.

27. It is important to note here that the estimates of damage resulting from air attacks came only from aerial post-raid reconnaissance. The accuracy of these estimates was unreliable. It was impaired by faulty pre-raid intelligence regarding building identification. The product of the plants was sometimes mistakenly reported; estimated production was wholly in error in these instances and therefore the damage figures were inaccurate.

28. This, as well as the fact that the bombing of the explosives industry, or the plants supplying raw materials needed for production of explosives, was not undertaken at earlier stages of the war can only be explained by the reluctance of the strategic bombing staff to use men with sufficient scientific and engineering background.

29. The bombing of the raw material plants affected other industries, which normally maintained a six months reserve supply of explosives were forced to utilize this reserve, and there was said to be a shortage of coal as a result of explosives shortages.

30. Conclusions: It may be said that little loss of production resulted from direct bombing attacks against the powder and explosives industry. A total of not more than 30 per cent of the manufacturing capacity for powder and explosives was knocked out by bombing attacks which occurred late in the war. Owing to the large excess production capacity which the Germans built in expectation of bombing, the actual

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production was never reduced below that for which raw materials could be supplied. Raw material supply was the bottleneck throughout.

31. As the plants were well isolated from large cities and other installations subjected to area bombing, area attacks had no detectable effect on the industry, except that production was lowered because of absenteeism and shattered morale. For the most part, the production units had their own power plants, and always had high priority in obtaining needed power from the grid system.

32. The really serious loss in powder and explosives production came as an indirect effect of the destruction of the large synthetic oil, ammonia, and methanol plants at Leuna, Oppau, Linz and Heydebreck. The primary object of these attacks was the destruction of the synthetic fuel production. Ammonia and methanol curtailment was an unintended and unexpected bonus. These attacks resulted in shortages of Hoko nitric acid, methanol, formaldehyde, hexamine, penta-erythritol, toluene and ammonium nitrate, which cut explosives production to one third and powder production to one half in the period July 1944 to February 1945.

33. As the Germans had built up an enormous reserve of filled munitions since 1944 (extimated in 1943 to be adequate for ten months at the maximum rate of consumption experienced up to that time), the effect on the war effort was not immediately evident. It would have become more important had the war lasted longer. No information was obtained as to the rate at which the reserve stocks were depleted by consumption, destruction by bombing and capture from the date of the Normandy invasion to the end of the war. However, General Henrici, who was in charge of German munitions development and procurement, expressed the opinion that the Allies could have put Germany out of the war a year earlier by concentrating their bombing effort on the synthetic ammonia plants. The Germans made every effort to maintain secrecy as to the nature of this nitrogen bottleneck.

34. The quality of the munitions fillings suffered increasingly from August 1944 to the end of the war, as a result of the use of increasing quantities of rock salt as a diluent, non-explosive extender. Unfortunately, no information was found as to whether any munitions with diluted fillings were ever used by the Wehrmacht, and if so, how effective they were. However, laboratory tests showed that the fragmentation effect was considerably weakened despite the opinions of Lt Col Soika of Heereswaffenamt to the contrary.

35. The number of direct attacks on powder and explosives plants was too small to justify any sweeping conclusions as to the best methods of attack, but the following may be advanced tentatively:

a. The most vulnerable part of the whole powder and explosives

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set-up in Germany was the four large methanol and ammonia plants which were knocked out incidentally to the bombing of synthetic oil plants in the same works. They comprised a small number of concentrated targets.

b. Next in order of vulnerability would have been the seven largest explosives plants; which comprised 70 per cent of Germany's TNT capacity.

c. The bombing of the railway lines, on which the industry depended for transportation of raw materials and finished products had a considerable indirect effect on the industry.

d. The destruction of two plants making powder stabilizers at Uerdingen and Wolfen would have shut down practically all of the powder plants. The Uerdingen plant was particularly vulnerable to an attack.

e. The synthetic toluene plant at Waldenburg would have been a good target also.

f. With regard to direct attacks on the industry as a whole, there were at least 35 important units well dispersed throughout Germany.

36. Each plant was spread over a large area with a low built-up factor. Area bombing tactics are indicated. Incendiary bombs appear to have done the greatest damage, both by direct destruction and secondary explosions. It is suspected that incendiaries would have been especially effective against those plants built in evergreen forests. In fact Dr Sarrazin said he had been very much worried about this hazard. Although there was usually considerable explosive material around one of the plants, secondary explosions by detonation of HE bombs could not be depended upon. In one case (Troisdorf) a 500-lb GP fell between the blast wall and a magazine containing 1,000,000 detonations; the wall of the magazine caved in, but no secondary explosion followed. A 1,000-lb GP bomb (Troisdorf) fell within four feet of a railroad car loaded with nitro-penta but the car and its contents were left undamaged. In one or two cases, cannon shell exploded 200 tons of nitro-guanidine which is normally considered to be insensitive. Bombing with a mixture of incendiaries and heavy and light HE bombs with delay and instantaneous fuzes is recommended. Bombing with high explosives alone was not so very effective because of the low built-up factor and the protective measures used.

37. Blast and fragment protection walls made of brick and sandbags on a steel framework appeared to be effective. Decentralized fire protection squads supplied with a waterpipe network, complete blackout control and efficient air raid warning service were necessary.

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GERMAN PRODUCTION
OF
NITROCELLULOSE
IN METRIC TONS

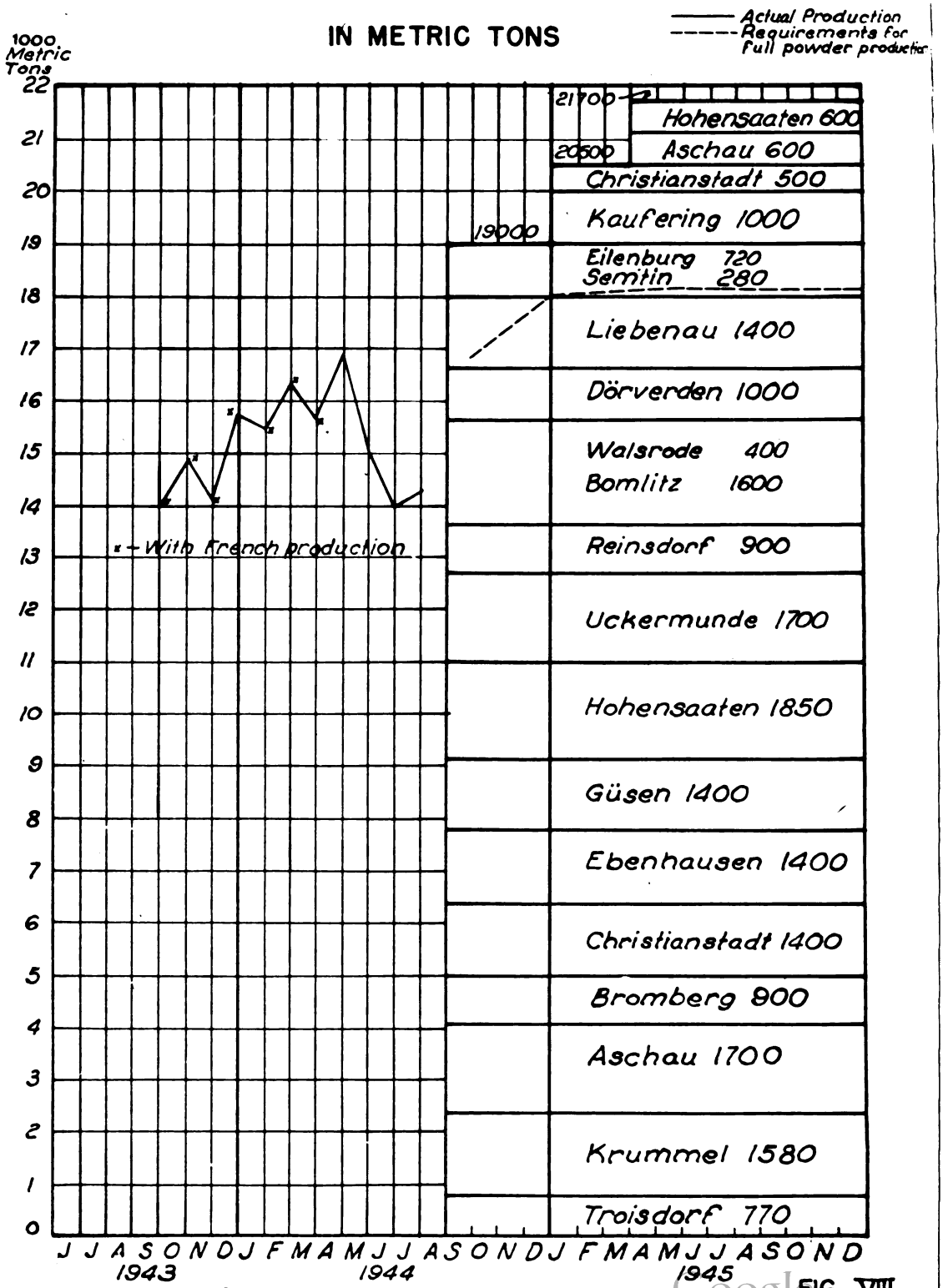

FIG. VIII

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PRINCIPAL GERMAN POWDERS AND EXPLOSIVES

Table 15

Trade name	Chemical name	Principal raw materials		
		Direct	Intermediate	Basic
		High Explosives		
TNT	Trinitrotoluene	(1) Highly concentrated nitric acid	Ammonia	Coal, water and air
		(2) Toluene	Coal tar	Coal
		(3) Synthetic Toluene	Benzene	Coal
Penta (PETN. Nitropenta)	Pentaerythritol tetranitrate	(Highly concentrated nitric acid	Ammonia	Coal and air
		(Pentaerythritol	Formaldehyde	Methanol, coal, water & air
			Acedaldehyde	Acetylene, carbide, coal
Hexogen	Cyclotrimethylenetrinitramine	(Highly concentrated nitric acid	Ammonia	Coal, water and air
		(Hexamethylene tetremine	Formaldehyde	
			Ammonia	Methanol, coal, water, air
Picric acid	Trinitr phenol	(Highly concentrated nitric acid	Ammonia	Coal, water and air
		(Phenol	Coal tar	Coal
Di (DNB)	Dinitrobenzene	(Highly concentrated nitric acid	Ammonia	Coal, water and air
		(Benzene	Coal tar	Coal
PH salt	Ethylene Diamine Dinitrate	(Ordinary nitric acid		Ammonia
		(Ethylene diamine	Ethylene	Alcohol, cokery, gas or carbide
			Ammonia	Ammonia
MAN Salt	Methylamine nitrate	(Ordinary nitric acid	Ammonia	Coal
		(Methylamine	Methyl alcohol	Water
Tetryl	Trinitrophenylmethylnitramine	(Complex synthesis)		Coal, water, air

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PRINCIPAL GERMAN POWDERS AND EXPLOCIVES

Table 15 (Cont'd)

Trade name	Chemical name	Principal raw materials		
		Direct	Intermediate	Basic
		Powders		
Nitrocellulose	Nitrocellulose	(Cellulose		(Wood or cotton linters
		(Highly concentrated nitric acid,	Ammonia	Coal, water and air
Nitrocellulose	(Nitrocellulose) (Nitroglycerin) (DEGN)	(Glycerin		Animal and vegetable oil and fats
•POL Powder	(Compound of Diethyleneglycol) (Dinitrate or Nitroglycerin) (and Nitrocellulose)	(Diethylene (Glycol)	Ethylene oxide	(Acetylene Ocalcium (Carbide-coal
		(Highly concentrated nitric acid	Ammonia	Coal, water and air
Black Powder		(Saltpeter		
		(Charcoal		(Wood
		(Sulfur		(Sulfur

• Solventless cordite (powder without solvents)

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38. Owing to the lateness of the attacks on the powder and explosives plants and the large unused capacity at the time, little effort was expended in repairing bombed out plants.

III. SPECIAL PROPELLANTS FOR ROCKETS, V-WEAPONS, JET PROPELLED PLANES, JET U-BOATS, ETC.

1. Development Throughout the War. The forerunner of the principle involved in rockets, V-weapons and jet propelled planes and U-boats in Germany was the Nebelwerfer, a multi-barreled rocket projector which fired projectiles filled with smoke acid, chemical agents or explosives. This was developed prior to the war. The propellant for the Nebelwerfer projectile was a molding of POL powder (solventless cordite). POL powder is particularly suitable for this purpose because it can be consolidated in massive form without the difficult operation of subsequent solvent removal. The Germans developed a method of, and screw press apparatus for the continuous plasticising and extruding of POL powder in large rods for rocket propellants. Powder was also used as a propellant for field rockets and for the catapults by which jet propulsion airplanes were launched.

2. Exhibit RA shows the volume of powder production for Nebelwerfer and 15 and 28 cm rocket projectors at Dueneberg during 1944. Exhibit RB shows the planned production of powder propellants for Nebelwerfers in Greater Germany for the first four months of 1944. Some Germans objected to the use of powder propellants because the powder, burning at a constant rate, gave a constant impulse and therefore lacked controlled variability.

3. During the war, several new liquid propellants for rockets, V-weapons and jet-propelled airplanes and submarines were developed by intensive research along these lines in Germany. A large research station staffed with first-class physicists, chemists and engineers was established at Peenemunde for the development of rockets and their propellants. Jet propelled submarines were in development at Kiel. BMW (Bayerische Motorenwerke) Flugmotorenbau GmbH was engaged in development of jet propelled planes for the Luftwaffe.

4. In the early work, exploratory experiments were made with various oxidizing materials and combustibles already available in the chemical industry. From these the work led to materials which, while not readily available, could be produced in the quantities required. The principal oxygen carrier finally selected was concentrated hydrogen peroxide (85 per cent) which was known as T-stoff. With it was used hydrazine hydrate (B-stoff), pyrocatechol or crude oil as a combustible. A permanganate catalyst (Z-stoff) was used for decomposition of the perixide. Liquid oxygen was also used in combination with methyl or ethyl alcohol. Highly concentrated nitric acid (Hoko) was used

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experimentally in combination with methyl alcohol, petrol or light diesel fuel, or a mixture of 80 per cent furfuryl alcohol and 20 per cent aniline, but owing to the short supply and corrosion difficulties, Hoko acid was never used very extensively. Other fuels were visole (vinyl-ethers) and xylidines, triethylamine and other organic amines.

5. In 1940, the Luftwaffe attempted the development of a plane which burned aviation gasoline with nitrous oxide (N_2O) instead of air in order to obtain greater acceleration. I.G. Farbenindustrie was assigned the task of building four plants for production of the nitrous oxide, two at Oppau and Hoechst in Germany and two near Lille in France. Each was to have a capacity of about 20-25 tons per day of nitrous oxide by heating ammonium nitrate with a catalyst. Apparently this project was never carried through aggressively, as there was no record of important production and use of this oxygen carrier. The plants in France were never finished and put in operation because the two in Germany were able to supply the experimental requirements of the Luftwaffe.

6. The entire field was in the process of development during the war and had not reached the more stable state of organized production existing in the powder and high explosives industry. In the early stages of development, established manufacturers such as I.G. Farbenindustrie, Degussa (Deutsche Gold and Silber Scheideanstalt) and EWM (Elektrochemische Werke Munchen) supplied oxygen carriers and fuels, and were given research contracts for the development of manufacturing processes for 35 per cent hydrogen peroxide, (normally produced in large quantities as 20-35 per cent H_2O_2), and for hydrazine hydrate.

7. The details of the processes involved in the manufacture of 85 per cent hydrogen peroxide and of hydrazine hydrate are disclosed in Plant Report No. 47 of the Oil Division, US Strategic Bombing Survey, dealing with Elektrochemische Werke, Munchen AG, Hollriegelskreuth, Germany, (Exhibits RF and RG) show diagrams of hydrogen peroxide manufacture. It is sufficient for the present report to indicate that 85 per cent hydrogen peroxide is prepared by concentrating 30 per cent material in special distillation equipment, the 30 per cent product coming from the electrolysis of sulphuric acid or of ammonium bisulfate. In producing the 30-35 per cent product, potassium persulphate was precipitated from the electrolysed solution. This was treated with sulphuric acid carefully purified of iron, copper and platinum and the hydrogen peroxide was distilled through a fractionating column under vacuum, and stabilized by addition of small quantities of oxyquinoline and pyrophosphate; for example .3 gr/l of solium pyrophosphate and .1 gr/l of oxyquinoline. This product was further concentrated in special plants such as those at Hollriegelskreuth and Bad Lauterberg by a two-stage fractional distillation which gave products of 72 per cent and 80-85 per cent for the first and second stages, respectively. The highly concentrated product

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was again stabilized with phosphoric acid (10 mgr per 1 liter).

8. Intensive research and development work on the production of concentrated hydrogen peroxide continued throughout the war, particularly with the objective of eliminating the necessity for platinum electrodes in the electrolytic process. A new method for the production of hydrogen peroxide, worked out by I. G. which was to have been used in the new plants at Waldenburg and Heydebreck, depended on reaction of gaseous hydrogen and oxygen in certain solvents which act as catalysts. This method produced a grade of material which was unsuitable for use in Walter U-Boats. The output of the two plants was to have gone entirely to the Luftwaffe. It is interesting to note that at a conference held 18 January 1945 it was decided by Speer to convert Luftwaffe weapons and jet planes from T-stoff (hydrogen peroxide 85 per cent) to Hoko (nitric acid) as the oxygen carrier. The T-stoff was to be used in U-boats, where neither Hoko nor liquid oxygen appeared to be satisfactory.

9. Hydrazine hydrate was prepared by the controlled reaction of sodium hypochlorite with ammonia, and final concentration and purification was accomplished by distillation.

10. Permanganates were used as catalysts for the release of oxygen from hydrogen peroxide at the time of combustion. They were known as Z-stoffe. Z-stoffe-N was sodium permanganate and Z-stoff-c calcium permanganate. They were made from potassium permanganate by the Permutation-exchange - reaction with calcium chloride or sodium chloride. The calcium or sodium permanganate was purified by fractional crystallization. (Exhibit RH gives process diagram.) The entire production was concentrated in the Hollriegelskreuth Plant of Elekrtochemische Werke Munchen. An additional plant had been planned at Lunzenau but construction was not completed when the war ended.

11. The production of 85 per cent (T-stoff) on a large scale apparently got under way in 1941 in the Hollriegelskreuth plant of Elekrtochemische Werke Munchen. A second plant was built by Otto Schickert at Bad Lauterberg in the Harz Mountains, which came into production in 1942. But the Hollriegelskreuth plant and the Bad Lauterberg plant were owned by the Pietzsch-Adolph-Schickert family. The same group organized the firm Chemische Fabrik Gersthofen v Transsche & Co K.G. for the production of hydrazine hydrate (B-stoff). They were also building a large T-stoff plant at Rhumsprings and others were planned. Exhibit RC shows the location of the plants producing special propellants and their capacities.

12. The plants for production of T-stoff had to be integrated with plants for the production of 30-35 per cent H_2O_2, most of which was made by an electro-chemical process. At Hollriegskreith both materials were produced. But the concentrating capacity there was far in excess of production of 35 per cent hydrogen peroxide and this excess capacity was

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GERMAN PRODUCTION AND PLANNED CAPACITIES OF B-STOFF AND T-STOFF IN METRIC TONS

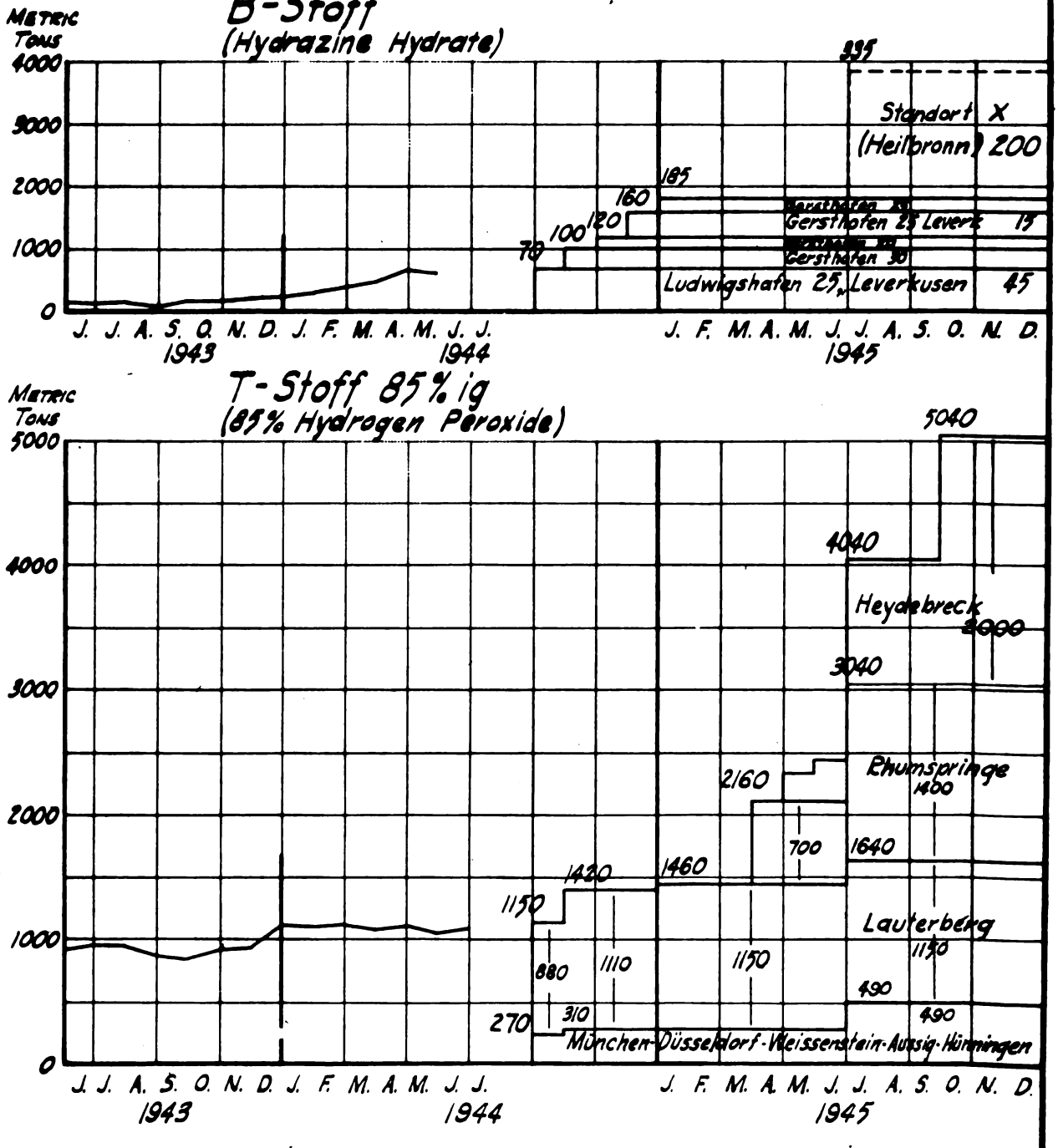

FIG. IX

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T – STOFF

HYDROGEN PEROXIDE PRODUCTION

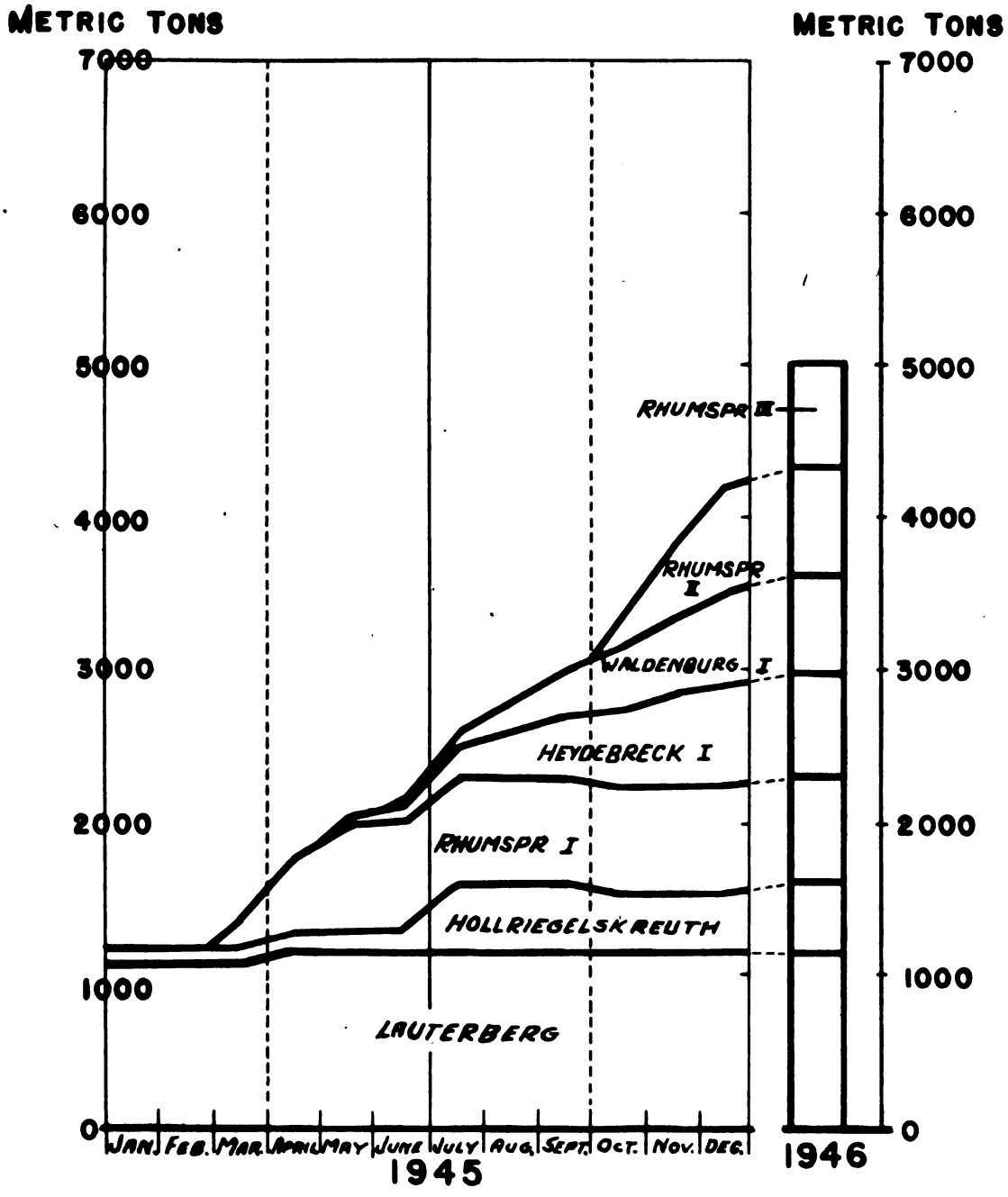

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FIG. X

T-STOFF

(Hydrogen Peroxide 85%)

Uses

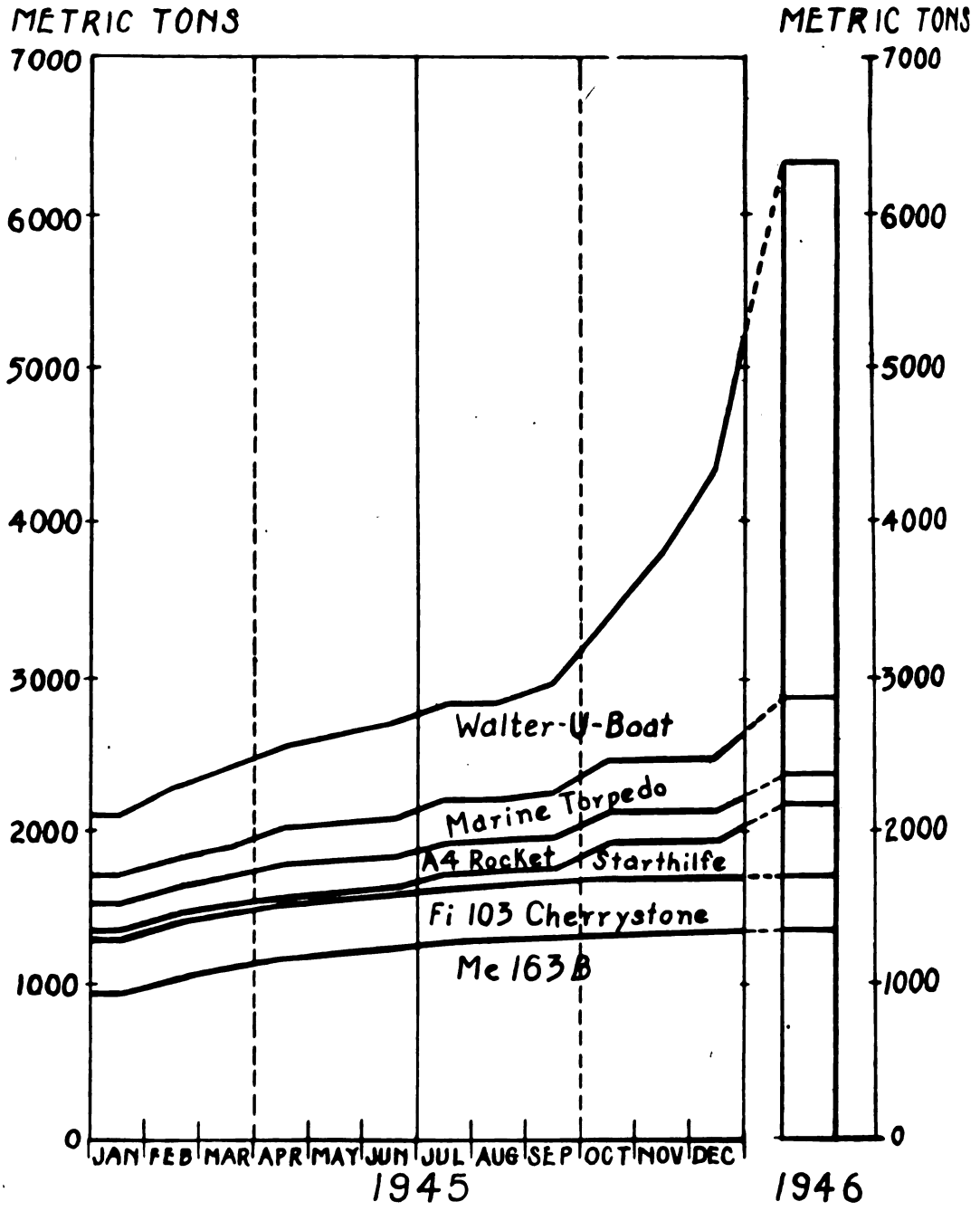

FIG. XI

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Table 16

GERMAN HYDROGEN PEROXIDE PRODUCTION

Company	Location	Process	Metric tons per month
Osterriche Chem Werk	Weissenstein	Sulphuric acid	200
Riedel	Kufstein	Ammonium bisulfate	200
Henkel & Co	Dusseldorf	Ammonium bisulfate	160-180
Kali Chemic	Honningen	Barium peroxide	120-150
Degussa	Rheinfelden	Sulphuric acid	400
(Degussa projected 200 tons per month by ammonium bisulfate method)			
Electro Chem Werke, Munich	Hollriegels-kreuth	Ammonium bisulphate	535
Otto Schickert & Co	Bad Lauter-berg	Ammonium bisulphate	3,500
El Chemie	-	-	150
Chem Fabrik Aussig	-	-	30
Zomkowitz	-	-	25

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used for the purpose of concentration of peroxide made in other plants and delivered to Munich in tank cars. Table 16 shows the plants and capacity for the production of 35 per cent H_2O_2.

13. The government required all producers of 35 per cent H_2O_2 to furnish 70 per cent of their production for concentration to 85 per cent H_2O_2 for the rocket program. The other 30 per cent could be used for the usual outlets.

14. Exhibits RD and RE are charts translated from the S Buch for Normal and Special T-stoff, respectively. The difference between the two lies in their stability. One product, T-stoff Special, to be used by the Navy, had to be very stable. The other, used by the Luftwaffe required less stability and hence less stabilizer. They show that production was much in excess of consumption and stocks were accumulated in the period 1941 and continued through mid 1943. Tank storage facilities were constructed for the material in various dispersed locations, in some cases in powder plants.

15. Unfortunately, similar data are not available for production of hydrazine hydrate (B-stoff) during the early years of the war. It is believed that the same trends were occurring with this material, but the volumes were not nearly so large.

16. Developments of Hoko (nitric) acid and fuel combinations were being conducted, but owing to the shortage of Hoko acid, were not encouraged. Many fuels available or readily produced by the chemical industry were being considered: Visole (vinyl ethers made by the Peppe process) xylidine, diethylamine, aniline and other amines, furfuryl alcohol, etc. Imports and exports were unimportant.

17. Although these special propellants were of great importance to Germany's rocket and jet propulsion program, their importance to Germany's overall industrial economy was small, and labor requirements were very small. The program was always given a high priority. It was consolidated with the PSV program under Gebechem in 1943.

18. In 1943, a requirement was established for 15,400 tons per month of 75 per cent ethyl alcohol (or 12,000 tons per month) for the A-4 rocket, which later became the V-2. In case the requirement could not be filled entirely with ethyl alcohol, it was intended to use one-third methanol and two-thirds ethyl alcohol. It was decided to draw on the fuel alcohol supply of France for part of the requirement (?,000 tons per month) not readily available in Germany and replace with gasoline rather than to take it out of the drinking alcohol supply of the Wehrmacht. The oxidizing agent for this apparatus was mainly liquid oxygen, with a small requirement for T-stoff as shown in Exhibit RF.

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19. In addition to the main hydrogen peroxide-hydrazine hydrate propellant system, intensive development work was carried forward on other propellant systems during the period. A "monergole" or single material embodying both the oxygen carrier and the combustible factor in the same molecule, but requiring outside ignition by spark or pyrotechnic device was found in methyl nitrate produced under the name of Myrol. Apparently, it was not used to any great extent, as large scale production never developed for this application. Myrol was, however, used as an explosive.

20. Systems which received the most attention were the so-called "hypergole" systems, comprising, amongst others, Hoko acid and an organic material which would spontaneously ignite on contact with the Hoko. The following are the principal fuels and the production picture:

21. Vinyl ethers (Visole) The lower vinyl ethers made in the Ludwigshafen plant of I.G. Farbenindustrie were partly used as rocket fuels under the code name Visole. The total production and the quantities allocated to use as rocket fuels in 1943 and 1944 are shown in Table 17. It is obvious that only a small fraction of the total production of these materials were used for this purpose. Another plant was being built at Auschwitz to assure production in case Ludwigshafen was bombed out. In the last months of February to May 1945 there was no production, owing to lack of acetylene.

22. Crude Pyrocatechol (Optol) This material was extracted by the Phenol-Solvan process from tars and aqueous fraction produced by low temperature carbonization of coal at Bruer and Blechhammer.

Production figures for 1944, in tons per month were as follows:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Planned	700	800	900	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Actual	349	135	321	168	220	184	169	-	77	384

23. It was found that uninterrupted operation could not be depended upon at Bruex because of air raids. A full shutdown at Bruex in the fall of 1944 seriously hampered total production. A dispersal plant of 150 tons per month capacity was being built at Erkner to come into operation in August 1945 and another in Leuna at the Brikett Fabrik Theissen. Underground plants were included in the Geilenberg program under the code name "Molch".

24. Furfuryl Alcohol (Fantol) The following plants, with capacities indicated, manufactured this material:

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Wolfen Filmfabrik	15 tons per month
Wolfen Filmfabrik	70 " " "
Mannheim Rheinau	30 " " "
Holzminden	8.5" " "
Tornesch	5 " " "
Wittemberge	75 " " "
Herdenau	30 " " "
Walsum	50 " " "

Although there are no data available on production, it is certain that the quantity used for rocket fuel was only a small fraction of total production.

25 Xylidines (Roxyl) Xylidines were manufactured by I.G. Farbenindustrie, Leverkusen, and Mulhausen Chemische Werke by nitration of xylenes produced as a by-product of the Waldenburg toluene synthesis and reduction of the nitro derivative. The average production was 35 tons per month in 1942, 45 tons per month 1943, and 45 tons per month in 1944. An I.G. representative estimated that 100 tons of Xylidines had been delivered to Bayerischen Motorenwerke for jet propellants. Triethylamine was made at Ludwigshafen as a by-product of the manufacture of diethylamine. Ordinarily the triethylamine was reprocessed to make diethylamine, but in the months of May, June, July and August 1944, the entire production was reserved for Bayersichen Motorenwerke. Production and deliveries (tons per month) for 1944 were as follows:

	Apr	May	Jun	Jul	Aug	Sep	Total
Production	60.7	16.2	38.7	42.2	11.1	-	168.9
Delivery to BMW	9.4	12.7	1	26.3	56.8	25.3	131.5

26. Air attacks on the plant in August and September stopped further production and burned 38.5 tons.

27. A 50-50 mixture of Triethylamine and Xylidine was used as a preferred rocket fuel under the code name Tonka 250.

28. Other aromatic amines which were used were aniline, monoethylaniline, and monomethylaniline. In general the relatively small quantities of these amines used for rocket fuels were withdrawn from the large production of seven or more chemical plants making dyes, powder stabilizers, pharmaceuticals and various other organic chemicals.

29. A mixture of aniline and monoethylaniline was made at Ludwigshafen under the code name "Anis-Manis". About 37 tons of this material was made in the years 1942 and 1943.

30. Other organic materials used as rocket fuel components were:

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Table 17.

Production in 1943 of the Lower Monomeric Vinyl Ethers and Allocations to Visol (Figures in Metric tons).

roduction in Tons	Jan	Feb	Mar	Apr	May	Jun	Jul	August	Sept	Oct	Nov	Dec	Total
Vinylethylether	89.9	89.6	63.7	52.5	66.5	59.6	58.1	2.8	94.7	74.2	-	115.8	767.4
Vinylisobutylether	228.1	172.6	260.1	318.2	166.1	312.8	174.5	264.0	109.2	257.6	301.1	136.8	2,701.1
Vinyl-n-Butylether	15.8	9.4	-	-	-	-	-	38.6	-	-	-	-	63.8
Vinylmethylether	-	-	39.8	-	44.6	-	45.1	-	-	-	42.6	-	172.1
Total	333.8	271.6	363.6	370.7	277.2	372.4	277.7	305.4	203.9	331.8	343.7	252.6	3,704.4
Delivery for Visol in tons													
Vinylethylether	-	-	-	-	-	-	1.5	3.5	20.6	-	9.0	-	34.6
Vinylisobutylether	-	-	-	-	-	0.2	-	-	-	0.2	0.3	0.1	0.8
Vinyl-n-Buthylether	1.0	12.6	0.3	-	-	0.2	6.0	4.9	4.7	-	-	31.5	61.2
Vinylmethylether	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.0	12.6	0.3	-	-	0.4	7.5	8.4	25.3	0.2	9.3	31.6	96.6

Total Production 1943 : 3,704.4 tons

Delivery for Visol 1943 : 96.6 tons

Production in 1944 of the Lower Monomeric Vinyl Ethers and Allocations to Visol (Figures in metric tons)

Production in tons	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Vinylethylether	104.9	65.0	98.9	93.6	184.0	167.9	134.9	178.0	67.3	37.6	142.3	85.0	1,359.4
Vinylisobuthlether	256.9	174.5	234.9	151.9	110.1	86.1	77.7	0.2	-	-	-	-	1,092.3
Vinyl-n-Butylether	-	-	-	-	-	-	-	-	-	-	-	-	-
Vinylmethylether	1.5	-	42.5	-	-	-	52.6	-	-	-	-	-	96.6
Total	363.3	239.5	376.3	245.5	294.1	254.0	265.2	178.2	67.3	37.6	142.3	85.0	2,548.3
Delivery for Visol in tons													
Vinylethylether	30.7	29.2	54.5	58.6	92.0	74.9	2.5	146.4	37.6	-	115.0	-	641.4
Vinylisobutylether	0.3	-	0.2	-	-	0.1	-	0.1	-	-	0.1	-	0.6
Vinyl-n-Butylether	-	-	-	-	-	-	-	-	-	-	-	-	-
Vinylmethylether	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	31.0	29.2	54.7	58.6	92.0	75.0	2.5	146.5	37.6	-	115.1	-	642.2

Total production 1944 : 2,548.3 tons
Delivery for Visol 1944 : 642.2 tons

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Diethyl ether
Tetrahydrofuran
Xylene - produced as by-product of the Waldenburg toluene plant.
Heavy gasoline

31. Various mixed fuels such as the following were used:

a. Pyrocatechol (Optol), Aniline, Furfural (Fantol) = Ofan.
b. Pyrocatechol + Aniline = Optan.
c. Pyrocatechol + diethyl ether = Optyl.

32. In late 1944, Bayerischen Motorenwerke developed the complex fuel mixtures Tonka 505c and Ergol 57h for use with Hoko acid in the large flak rocket and the jet-propelled Messerschmidt plane.

Tonka 505c			Ergol 57h	
Aniline	5%	(wt)	Aniline	10%
Anis Manis	7	"	Aromatic gasoline	11
Aromatic gasoline	18	"	Monoethylaniline	9
Diethyl ether	25	"	Pyrocatechol	15
Pyrocatechol	18	"	Crude Xylidines	12
Crude Xylidine	12	"	Tetrahydrofurane	15
Xylene	15	"	Xylene	28

33. Research and development on new jet propelled U-boats, airplanes and rockets had been carried forward aggresively. The main interruption was the bombing of Peenemunde, which was said by Engineer Larrson and Dr Dickmann to have delayed the development of newer V-weapons. However, Reichsminister Speer stated that the development of V-2 was completed prior to this raid. The following new weapons were being brought into large scale production or were in late stages of development at the beginning of 1945:

X-4: An airborne rocket weapon.
Equipment 8-117: ("Butterfly") - an anti-aircraft rocket fired from the ground.
Me 143 C - Messerschmidt jet-propelled fighter plane.
"Ensian" - a large radio directed anti-aircraft rocket carrying an explosive charge of 500 Kg.

Further details are given in Exhibit RK.

34. The German Navy had also some new models of jet-propelled U-boats and marine torpedoes.

35. Germany was anxious to take full advantage of these new and

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superior implements on which it placed so much hope of getting out of a military situation which was growing more critical daily. Very early in January 1945, a survey was made of the possibilities of producing propellants for the expanding rocket program. The requirements for new devices developed by the Luftwaffe for 1945 were stated to be as shown in Table 18.

36. The requirements for the older Luftwaffe rocket apparatus for the year 1945 were estimated as follows:

	Hoko Acid	Optolin	C-stoff	T-stoff	Z-stoff
Airplane FZG76/launcher	-	-	-	4,186	254
Airplane 8-163/8-263	-	-	6,756	20,575	-
Anti-aircraft rockets	1,141	552	-	12	-

37. The Luftwaffe estimated its B-stoff consumption for late 1944 and early 1945 to be as follows (metric tons per month):

Nov	96
Dec	124
Jan	159
Feb	194
Mar	232
5 mo Total	805

38. Against these requirements, the accumulated stocks held by Wifo on 31 December 1944 were as follows:

Storage	T-stoff Special	T-stoff Normal	Visol	Roxyl	Optan	Optolin	Optyl 70	Kondensat
Farge	--	--	14	8	15	61	--	--
L 6	--	140	-	-	-	-	--	--
L 7	--	--	530	-	-	-	--	--
L 9	572	--	-	-	-	-	--	--
L 10	910	--	-	-	-	-	--	--
L 22	3	--	-	1,020	421	-	146	4
L 24	1,348	643	-	-	-	-	--	--
L 32	--	72	-	-	-	-	--	--
Lollend	105	--	-	-	-	-	--	--
Total	2,938	855	544	1,028	436	61	146	4

39. Table 20 shows the total stocks of T-stoff to be 8,440 tons, the difference being in the quentities stored at installations of OKL,

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Table 20

REQUIREMENTS FOR X 4, SCHMETTERLING UND R-RUSTSATZ

	8 - 34 (X 4)	8 - 117 Schmetterling ("Butterfly")	718 R-Rustsatz (Airplane Rocket)	Total
	Tons	Tons	Tons	Tons
Triethylamin	20	--	--	20
Xylidin (Roxyl)	20	66	336	422
Anilin	--	28	140	168
Ethylanilin	--	39	196	235
Optollo	--	99	505	604
Xylol	--	82	420	502
Ethylether	--	137	700	837
Aromatic gasoline	--	99	505	604
Tonka 250	40			
Tonka 505 c	--	550	2,802	3,352
Moko (Nitric Acid)	140	2,560	10,000	12,700
Hoko (Nitric Acid) for production of amines		90	500	590
Total Hoko Acid	140	2,650	10,500	13,290

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TABLE 19

T-STAFF REQUIREMENTS FOR U-BOATS ACCORDING TO SITUATION OF 5 NOVEMBER 1944

STAMP: HIGH COMMAND OF THE NAVY

Requirements month	New construction		Boats now in operation				Repartition of the requirements on T Staff					Total required tons in a month
	XVII B	XXVI W	Exp. boats Type XVII	Type XVII B	Provisional boats Type XXVI W	Type XXVI W	Test station	Exp. boats Type XVII	Type XVII B	Provis. boats Type XXVI W	Type XXVI W	
1	2	3	4	5	6	7	8	9	10	11	12	13
1944												
November	-	-	3	-	-	-	150	180	-	-	-	330
December	1	-	3	-	-	-	150	180	-	-	-	330
1945												
January	2	-	3	1	-	-	150	180	38	-	-	368
February	-	-	3	1	-	-	150	180	115	-	-	445
March	-	-	3	5	-	-	150	180	190	-	-	520
April	-	1	3	5	-	-	150	180	190	-	-	520
May	-	1	3	5	1	-	150	180	190	50	-	570
June	-	-	3	5	2	-	150	180	190	100	-	620
July	-	-	3	5	?	-	150	180	190	100	-	620
August	-	?	3	5	?	-	150	180	190	100	-	620
September	-	4	3	5	?	?	150	180	190	100	100	720
October	-	8	3	5	?	6	150	180	190	100	300	920
November	-	10	3	5	?	14	150	180	190	150	700	1,370
December	-	12	3	5	?	24	150	180	190	200	1,200	1,970

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Table 20

PRODUCTION, CONSUMPTION AND STOCKS OF T-STOFF (85% HYDROGEN PEROXIDE) IN 1944 (METRIC TONS)

	Stocks (Tons)	Production (Tons)	Consumption (Tons)
Stocks 1/1/4/45	9,320		
Jan	9,842	1,102	786
Feb	9,549	1,100	1,069
Mar	10,079	1,138	717
Apr	10,553	1,057	632
May	10,655	1,101	883
Jun	9,703	1,056	1,699
Jul	9,139	1,109	1,759
Aug	9,739	1,279	1,101
Sep	9,517	1,146	984
Oct		1,189	1,280
Nov		936	1,140
Dec	8,441	1,027	

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OKM, and other non-Wifo storage facilities. The quantities of fuels stored in non-Wifo facilities is not known.

40. The production rate for T-stoff was 1,000-1,200 tons per month. Although the construction program for new plants to make rocket propellants had been spared when other phases of the PSV-Sector had been forced to give up men to the Jager program and Geilenberg Agency during the summer and fall of 1944, the production capacity for T-stoff was not expected to exceed 2,000 tons per month before the end of 1945. This was due to the large proportion of skilled hand labor required in the construction of such plants, which required at least 2½ years to construct. It was obvious that the T-stoff requirements of both the Air Force and Navy could not be supplied.

41. The Navy, which would not use Hoko acid propellants because of the tell-tale wake of bubbles, was asked to consider the use of oxygen instead of T-stoff in its submarines. However, calculations showed that the hull would have to be enlarged by 200 cu m, the maximum speed would be reduced to 20 knots and the range would be only one-half to two-thirds of that with T-stoff.

42. At a meeting 18 January 1945 of Speer, Kehrl and Krauch with officials responsible for jet-propelled weapons and propellants, the following decisions were made:

a. "The minister decided that Rhumspringe III (T-stoff plant) should no longer be built. The apparatus for this plant should continue to be ordered and should be utilized for repairing the damage, if any, from enemy attacks on the plants. The minister declines to authorize new construction of further T-stoff. The shifting of one of the projects underground is likewise out of question, because the building time would be at least 18 months.

b. "To eliminate the present uncertainty with respect to the I.G. T-stoff, Professor Krauch has promised to shift the experimental plant at Oppau to a safe location and to take steps that it is put into operation as soon as possible.

c. "The Me-163 B weapon will be supplanted by the Me-263. The output of these machines will be brought up to 100 of them per month. Furthermore, the air force has begun the project 'Natter'. As to the problem whether the Navy or the air force has the first call on the T-stoff, the minister said the following: The building of U-boats is in every respect more extensive and weighs on the armament industry to a much greater extent than does the building of the air force equipment. If the air force program is slowed down at that time when consumption by the navy expands, this can be easily borne by the armament industry because production for the air force occupies only relatively small

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quantities of material and plant capacity. The building of U-boats is therefore sensible only when the navy had priority over the air force with respect to supply of T-stoff. The air force equipment is in a sense to be regarded as stand-by equipment. The minister concludes that a decision should be obtained from Hitler after a combined personal report by Admiral Doenitz, General Diesing and himself.

d. "As far as U-boats are being built, in 1946 there should be still available 6,000 to 7,000 tons in stock.

e. "The minister is in favor of the development of rocket propulsion apparatus operating with highly concentrating nitric acid as oxygen carrier. The 'Natter' and the Me-263 weapon should be likewise converted to its use. The demand for it should be covered by the chemical branch. Professor Krauch adds at this point that the construction of highly concentrated nitric acid plants is substantially simpler than that of T-stoff plants. The minister is fundamentally of the opinion that the nitrogen and Hoko manufacture should be safeguarded and enlarged."

43. The air force was thereby forced to rely mainly on a supply of Hoko acid, which, owing to the bombing of ammonia plants had been insufficient to satisfy the requirements of the powder and explosives industry.

44. What the destruction of the T-stoff at Bad Lautenberg with its capacity of 1,000 tons per month would have done to Germany's rocket program is obvious from the foregoing discussion.

45. Performance of the Industry and Changes in Planning During the Course of Combined Bomber Offensive as Result of Both Direct Attacks and Indirect Attacks.

a. At about the same time that the combined bomber offensive began, the Germans were attempting to rationalize their broad rocket type weapon program. The jet plane had already proven its potential value to them as a weapon with which to meet formation bombing. Other weapons based on the use of special fuels were being developed as rapidly as possible. The rocket as an offensive weapon was held by some Germans to the source of hope for a victorious conclusion of the war. In mid-year 1943 they expected to be able to destroy the cities and military establishments in Britain. This would pin down the Allied air forces and force the Allies to fight a land war where the Germans thought they would have "a sure superiority". (Minutes of meeting in Berlin 29 June 1943 concerned with raw materials for R-program, Exhibit RI.) Table 21 gives a summary of the most important raw material requirements of the R-Program.

b. Of those materials listed in Table 21 only two, 85 per cent hydrogen peroxide and hydrazine hydrate, appear to be unique with respect to this program. The manufacture of the other materials was to have

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been largely the concern of the organic chemical industry. In fact, the need for haste dictated the policy considering as fuels any suitable organic compounds, already manufactured or occurring as by-products, which had previously no important war uses. One other class of materials, Z-stoffs, were required for parts of the R-Program, but production of these permanganates was considered adequate at the beginning of the program.

c. The lower part of Figure 9 shows the production throughout the period of the combined bomber offensive and the planned increases throughout the year 1945. The production, consumption and supply situation with regard to T-stoff is shown in Table 20. It is evident that production was maintained at a high level throughout 1944, and that consumption did not exceed production until mid-1944. Figures 10 and 11 show the expected production and distributed consumption of hydrogen peroxide (85 per cent) during 1945. (In this connection it appears, from data not available when Plant Report No 47 was written, that the production figures for German production of 85 per cent hydrogen peroxide as shown in Exhibit A of that Report are somewhat optimistic and may represent an overstatement of about 10 per cent.)

d. Although a heavy raid was carried out 19 July 1944, against the Elektrochemische plant at Hollriegelskreuth, that part of the plant which produced concentrated hydrogen peroxide 85 per cent escaped damaged almost completely. A few days' production was lost because the raid interfered with power and other facilities, but these were quickly restored in sufficient measure for the operation of the concentration plant. Although the facilities for the production of 30 per cent hydrogen peroxide at Elektrochemische were completely destroyed, this grade was shipped into Hollriegelskreuth from other plants for concentration, as had been the practice since the beginning of the R-program.

e. Elektrochemische Werke Munchen AG produced other materials of great importance to the R-program. These were the Z-stoffs, which were used as catalysts, or decomposition agents, for the release of oxygen from hydrogen peroxide. Indications were that the entire German output was centered in Hollriegelskreuth. This portion of Elektrochemische's plants suffered only superficial damage during the raid of 19 July 1944 and production was maintained at a 50 tons per month level.

f. The plant for manufacture of 85 tons per month hydrogen peroxide, located at Bad Lauterberg, was never bombed, and only two of the other German plants making 30 per cent hydrogen peroxide were ever hit. Some locations were bombed which intelligence reported as manufacturing points, but they were really nothing but storage points or use points. As indicated by their report for the month of December 1944 the Bad Lauterberg plant lost some production, perhaps indirectly as the results of bombing attacks.

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

Table 21

MOST IMPORTANT RAW MATERIALS
REQUIREMENTS FOR ROCKET PROGRAM
ON 30 JUNE 1943

Metric tons per month

Weapon	Units/No Expendable	Oxygen Carrier			Fuels		Powder	Explosives
		Hydrogen Peroxide 05%	Nitric Acid	Liquid Oxygen				
Fighter	10,000 Sorties	6,200	6,500	-	Methanol	800	2,000	2,000
					Hydrazine Hydrate	800		
					? (30% Amines and Visole)	1,600		
C-2 "Waterfall" Flak rocket	10,000	-	16,500	-	Visole	2,800	-	1,000
					?	1,200x		
A-4 Rockets (V-2)	900	500	-	13,500	Ethanol 95%	4,000	-	1,500
					Methanol	2,000	-	
FI-103 "Cherry stone"	3,000	300	-	-	Aviation Gasoline	2,100	-	4,500
					Ethanol	4,000		
					Methanol	2,800		
					Aviation Gasoline	2,100		
					Visole	3,000		
					Hydrazine Hydrate	800		
					Others	2,600		
Totals	23,900	7,000	23,000	13,000		30,600	2,000	9,000

x where (?) occurs it indicates that the Germans had not decided what materials were to be used to supply the tonnage requirements.

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g. It is unfortunate that plants producing hydrogen peroxide, so vital to the German rocket weapon program, were not put out of commission completely by the bomber offensive.

h. Hydrazine hydrate (B-stoff) was manufactured in three plants, and plans were being made for a fourth to come into production late in 1945.

i. The upper part of Figure 9, which was copied from the German report on the PSV Program dated 1 September 1944, shows the production through mid-year 1944 and indicates the planned capacity increases. Table 22 comprises data taken from records of the Speer Ministry. It should be noted that production of B-stoff was curtailed at both Leverkusen and Ludwigshafen in September 1944. The units producing this material were not damaged but destruction of facilities throughout the plant prevented their operation at previously maintained levels. This table also indicates that the Gersthofen plant came into production on schedule, although indirect causes prevented full-scale operation. There is no record showing Gersthofen as a primary bombing target.

46. Summary of Bombing Attacks on Industry

a. For a review of, and recommendations for, bombing of the special rocket fuel industry, data is at hand which covers only three such plants. They were Elektrochemische Werke Munchen AG and Gesellschaft fur Linde Eismaschinen AG, both located at Hollriegelskreuth, near Munich, and both considered as one air raid target, and Henkel and Cie GmbH, located at Holthausen. Such data are tabulated in Table 23.

b. For plants with large built-up factors, such as the three listed in Table 23 and having some heavy construction or equipment, the bomb loads made up of 500-lb, 1,000-lb and 2,000-lb HE bombs, with some incendiary bombs, are recommended. The bombs should include those having instantaneous fuzing and some with .025 fuze settings.

c. Being built, for the most part, of relatively light construction and equipment, the hydrogen peroxide and liquid oxygen plants were vulnerable in their entirety. Much of the equipment for the manufacture and concentration of hydrogen peroxide was either glass or chemical stoneware.

d. A storage reservoir in the Kraiburg explosives plant containing 300 tons T-stoff was hit by a bomb on 11 April 1945 and the T-stoff was destroyed by secondary detonation. In an attack on 4 November 1944 on the plant of the Stickstoffwerke Ostmark AG at Linz, four of the seven T-stoff storage reservoirs were completely destroyed. One was partially destroyed. Of a total of 800 tons, 600 tons were destroyed.

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Table 22

GERMAN HYDRAZINE HYDRATE
(B-STOFF)
PRODUCTION
METRIC TONS/MONTH

	Ludwigshafen		Leverkusen		Gersthofen		Total	
	Plan	Actually	Plan	Actually	Plan	Actually	Plan	Actually
1944								
January	-	6.4	-	16.1	-	-	-	22.5
February	-	17.0	-	13.6	-	-	-	30.6
March	-	13.3	-	26.9	-	-	-	40.2
April	-	15.0	-	35.1	-	-	-	50.1
May	-	18.9	-	47.8	-	-	-	66.7
June	20	17.4	40	42.6	-	-	60	60.0
July	22	19.0	43	45.3	-	-	65	64.3
August	23	17.0	45	46.1	-	-	68	63.1
September	23	-	45	40.0	30	-	98	40.0
October	23	4.3	50	12.3	50	5.0	123	21.6
November	23	13.0	50	3.0	75	20.5	148	36.5
December	23	7.5	55	12.9	95	22.8	173	43.2
1945								
January	23	-	55	-	125	38.5	203	38.5
February	23	-	55	-	150	-	228	-
March	23	-	55	-	190	-	268	-

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47. General Effect of Bombing of the R-Program Plants on Germany's Ability to Wage War.

a. This program was very important to the German plans for future operations. They had placed great confidence in the ability of their jet-propelled planes to stop the Allied bombing operations. Although the V-bombs were of questionable military value, Germany planned for the expansion of their use. They had even greater hopes for the new jet-propelled U-boats, and gave the U-boat program highest priority for fuel supply. The propellant plants were of critical importance to jet-propelled planes, U-boats and V-bombs. However, as only three hydrogen peroxide plants were bombed and the production equipment destroyed was that for production of 35 per cent H_2O_2 for which excess capacity existed, the bombing caused the loss of only a few days' production of T-stoff in one plant. As fairly large stocks were available, bombing of these plants had no effect on the rocket program during 1944 and early 1945. The amount of T-stoff stock destroyed at Linz and Kraiburg represented nearly one month's production.

b. The bombing of the research station at Peenemunde, however, killed some of the most competent personnel and set back the development program several months. (Three to four months on new V-weapons according to Dr. Liekmann and Engineer Larson.) Speer claims there was no delay on the V-2 because its development had been completed prior to the raid. Had the war continued through 1945, the shortage of Hoko acid brought about by the bombing of synthetic ammonia plants would have prevented the wide expansion of the rocket program which the Germans planned for 1945 and 1946.

48. Conclusions

a. A production loss of about 100 tons resulted from the bombing of the Hollriegelskreuth plant, and a total of 900 tons of T-stoff 85 per cent hydrogen peroxide stocks, was destroyed by bombs at Kraiberg and Linz. So far as can be learned, area bombing had no effect on the production of T-stoff or B-stoff. Owing to the large stocks of T-stoff accumulated from 1932 onwards this loss had no effect on the rocket program up to the end of the war.

b. Had the war continued, the shortage of highly concentrated nitric acid would have prevented the Germans from achieving their planned expansion of the rocket program unless the explosives and powder production were correspondingly robbed.

c. The production loss in T-stoff was probably much lower than estimated, as the important concentrating equipment at Hollriegelskreuth was practically undamaged and resumed full production after a pause of only a few days. The allocation of 30-35 per cent H_2O_2 to industrial

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

Table 23.

Plant	Area in acres	% Built up factor	Tons dropped HE	Tons dropped IB	Tons bombs in plant area	Tons bombs per acre	No of bldgs
Elektrochemische Werke Munchen AG	24	25)			32½	1.35	39
Gesellschaft fur Linde Eismaschinen AG	14	30)	266.5	-	30 3/4	2.2	26
Henkel & Cie GmbH	200	15	1	1	2 1/3	0.0116	55

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and civilian applications had to be reduced according to the production destroyed by bombing, but the production for the rocket program was maintained.

d. As the equipment used for 35 per cent H_2O_2 manufacture was glass and chemical stoneware, high explosive bombs were very effective. High explosives were found also to produce secondary explosions in storage of 85 per cent H_2O_2 (direct hit).

e. The plant at Bad Lauterberg would have been an excellent target as it was unprotected. The Germans depended largely on secrecy for its protection. As a large proportion of the T-stoff production was concentrated there, it was vital to the rocket program.

f. The bombing of the research laboratory at Peenemunde killed some of the best rocket experts and delayed developments in the rocket program by several months.

IV WAR GASES AND SMOKE ACID (NEBELSAURE)

1. Although war gases were never used by the Germans in their military operations, and neither their manufacturing plants nor stocks of these agents were ever deliberate targets for strategic bombing, a brief discussion of the German preparation for gas warfare will be included in this report because it was carried as a part of the PSV Program and it was indirectly affected by bombing. War gas was known during the first years of the war as D (Kampf) stoff, but the designation was later changed to C-stoff for security reasons.

2. Smoke acid (Nebelsaure) is of direct interest to the report for it was one of the most effective methods of protection against bombing. The following discussion is based largely on documents found in the files of the Speer ministry and Gebechen.

3. The "K-stoff" Program in Preparation for War

a. There is evidence of development work on war gases by I.G. Farbenindustrie prior to 1939 as I.G. correspondence revealed a controversy over inventorship concerning Mischlost, presumably a form of mustard gas. The I.G. plant at Leverkusen shipped thionyl chloride for the manufacture of poison gas as early as 1938 (21 tons) to Ammendorf, the site of a World War I war gas factory. Correspondence found by CIOS in the files of Dr Ter Meer, the TEA Dept and the Law Dept of I.G. shows that a definite plan for the participation of I.G. in the development of the German war gas program was drawn up at a conference in Berlin in February 1939.

b. I.G. organized a 100 per cent subsidiary Luranil, for the

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construction of plants and another one, Anorgana, for their operation. These were in reality cover names to conceal ownership and partly to relieve I.G. of responsibility, but the capital was owned by I.G. This firm also provided the key personnel. Montan, the government-owned corporation which functioned under control of OHK as shown already in Exhibit A, erected many of the plants with government funds and normally with the assistance of Organization Todt. Montan held title to such plants and leased them for operation to I.G. or other subsidiaries on contracts of three types: (a) lease of property to subsidiary of the industrial firm, (b) management contract with industrial subsidiary on a cost-plus-fee basis, (c) grant or loan to subsidiary for erecting uneconomic plants for war purposes. Montan was controlled by government officials, and Luranil and Anorgana by a mixed board of I.G. and government officials. Exhibit CA shows how the war gas activities (C-Program) fitted into the PSV Program.

c. Apparently I.G. did considerable research and development work on poison gases in its own laboratories.

d. In September, 1939, OHK requested I.G. to proceed as rapidly as possible with operations at Dyhernfurth, using a process stated to have been developed in Reich laboratories in Spandau and Reidkrug. The Orange Plan which provided for the expansion of war gas capacity to 15,000 metric tons per month was adopted 25 November 1939, but was abandoned in favor of more modest plans a few months later. Plans for phosgene shell filling plant at Wolfen were underway in December 1939. In March 1940, conferences were held concerning a plant to be built in Gendorf and to apply a process developed by I.G. Subsecouent planning was continuous and ever expanding until about mid-1944 when the program was seriously curtailed by shortage of labor, apparently as a result of loss of personnel to the Jager airplane program and the Geilenberg repair and reconstruction agency, both of which had higher priority. The program was, however, not entirely stopped at that time.

4. <u>The Program During the War Years</u>

a. Exhibit CB, shows a comparison of the production capacity actually reached through the period 1939 to 1942 inclusive with that planned in August 1938.

b. Apparently I.G. furnished the trained technical and supervisory personnel for the operation of the plants, and both war and political prison laborers were used. Two thousand were employed at Dyhernfurth. There appear to have been many arguments between I.G. and government officials over the suitability of such laborers for controlling the dangerous operations involved.

c. The following older and well-known war gases were made:

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(1) Mustard Gas (Lost, OL, DL) was made at the plant at Gendorf by two different processes. The plant was intended to use the Direct Process (Levinstein-DL) from ethylene and sulfur chloride, but the product was so unstable that the plant was converted to the Indirect Process (Thiodiglycol-OL) based on ethylene oxide. The plant at Gendorf started with carbide from Knapsack and acetylene was made from that. Electrolytic chlorine and sulfur were the other raw materials.

(2) Phosgene (Oel F) was made conventionally as was Chloracetophenone (O-Salz) and Adamsite (Azin). Azin was made at Uerdingen near Krefeld. From August 1940 to October 1944, at least 3,600 tons were made. CWSCIOS representatives were informed that it was mixed with a liquid toxic material and filled into projectiles.

d. The following new materials were developed:

(1) Arsinoel (A-Dil) was made from aniline, arsenic and chlorine. It was further processed to make Clark (Cl), and was also mixed with mustard to make winter-lost (OKM) a low freezing-point mustard. Clark I, was diphenylarsin-chloride and Clark II was diphenylarsincyanide. Another agent of this type was diphenylaminearsincyanide.

(2) Nitrogen mustard (T9) was made from ethylene oxide ammonia and chlorine.

(3) Sarin and Tabun were fluoro and cyane phosphates, respectively. They were made from phosphorus oxychloride. Sarin was rated by the Germans as six times as effective as Tabun. They were very toxic and very insidious in that they posessed practically no odor. They were Germany's main contribution to war gas development in this war.

e. Monomethylamine produced as a by-product of Tabun manufacture was used as a raw material for the explosive MAN.

f. Other war gases made in small quantities were T-150 (cyanogen chloride), and T-155 (Hydrocyanic Acid).

g. Exhibit CC shows the raw material requirements for the various war gases.

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h. Also included in the C-Program were activated charcoal for gas masks, Decontaminants 40, (trichlor cyamuric acid), weapons decontaminant (WEM, a solution of methyl sulfonamid dichloride in trichloroethyl phosphate), bleaching powder, Losantin (high test bleach tablets), decontaminating ointment, and sodium bisulfate (for decontaminating nitrogen mustard).

i. Exhibit CD lists the locations of the plants in the progra and shows the development of production capacity, and the status on 1 August 1944.

j. Exhibit CE is a graph of S Buch data showing the production capacity, actual production and accumulation of supplies up to the middle of 1943. Table 24 shows data for stocks and monthly production obtained from Speer Ministry and Gebechem files.

k. Stocks of mustard gas on 1 April 1944 were:

17,000	tons	thiodiglycol mustard
5,500	"	OKH winter mustard
2,500	"	direct (Levinstein) mustard
2,100	"	Italian
27,100	"	Total

l. This was considered adequate for five months of gas warfare. It was proposed to stretch the supply, if necessary, by adding up to 40 per cent of ethylene dichloride.

m. Exhibit CF is a statement of the army armament office of the status in 1944.

n. Exhibit CG is a section of the report prepared by OKH of progress in gas manufacture and filling for the period October 1943 to October 1944.

o. Exhibit CG is a table prepared for US Chemical Warfare Service by Dr Ehmann, showing the gas stocks existing at the end of the year.

p. The combined bomber offensive had considerable direct effect on Germany's war gas production although no attacks were made with the destruction of this manufacture as a specific objective. The phosgene plants at Ludwigshafen and Uerdingen, and the chloracetophenone plant at Ludwigshafen were destroyed by air attacks aimed at the large industrial chemical and oil plants with which they were integrated. The thiodiglycol plant at Huels was crippled by the air raid on the synthetic rubber plant. Except for partial damage to the Haselhorst plant in

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October 1944, there appeared to have been no attacks on the special war gas plants or on depot stocks.

q. Records show that the war gas program was seriously handicapped by indirect effects of the bomber offensive, such as shortages of raw materials and coal, and transportation difficulties. Taking mustard, which was recognized as the most important war gas, for example, the thiodiglycol process was generally adopted after early experience with the direct process (ethylene and sulfur chloride) resulted in a product having inadequate storage stability. The direct process, which consumed only about one-fifth as much chlorine as the thiodiglycol process was preferred from the manufacturing standpoint. The thiodiglycol process competed with glycol anti-freeze and double base powder (POL Pulver) manufactures for the important raw material, ethylene oxide.

r. When, as a result of air attacks on the carbide, ethylene and ethylene oxide plants and their auxiliaries, a serious shortage of ethylene oxide developed, it became necessary to cut back thiodiglycol mustard production materially and finally stop it almost entirely in late, 1944. Then frantic efforts were made to produce a stable product by the direct method and to complete the new plant construction planned and started earlier for this process. The purity of the plant product was about 90 per cent. While it could have been loaded directly into shells for shipment to the front in a gas warfare situation, it did not meet the Wehrmacht's stability specification for storage at 60°C in steel. It could be stored only in ceramic ware. Reasonable stability was obtained by refractionating the crude product from the direct process, and a fractionating column was planned. No mention could be found of the use of stabilizers. Before the expansion of the direct process could be effected, however, it was largely abandoned because of chlorine shortage.

s. Production of the very effective new gas, Tabun, was limited by shortages of methanol, ammonia and sodium cyanide resulting from air attacks elsewhere. In a letter to Keitel dated 11 October 1944, Speer stated that the 4,900-5,400 tons of methanol available to the powder, explosives and war gas program (which normally consumed about 9,000-10,000 tons per month prior to the attacks on Leuna, Oppau, Heydebreck, Auschwitz, etc) would be allocated as follows:

Toluene synthesis	1,000-1,500 tons
MAN salt	300
KA hexogen	300
SH hexogen	1,500
Nitropenta	1,400
Tabun	400
	4,900-5,400

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t. He expected that it would be necessary to discontinue Tabun manufacture by January 1945. However, the stocks of that gas could be stretched by addition of 20 per cent chlorbenzine.

u. The monthly reports for the period 1 September to 31 December 1944 contain the following pertinent items:

(1) The Chloracetophenone plant at Ludwigshafen was destroyed by air raids prior to September and produced nothing during the period. That of de Haen at Seelze had no production because of a lack of coal and methanol. That of de Haen at Hahnenberg was closed the whole period because of lack of operators and orders.

(2) The Arsinoil plant of Lonal at Leese was shut down the whole period and that of Ergethan at Stassfurth was limited by shortages of busulfite and sodium nitrate to an average of 50 per cent of its capacity.

(3) The Clark I plant at Haselhorst was damaged by an air raid in October and produced at 15-40 per cent thereafter.

(4) The Adamsite plant of I.G. at Uerdingen was knocked out in September and had no further production.

(5) No phosgene was produced during the period. The Ludwigshafen and Uerdingen plants of I.G. were destroyed by air raids and all plants were short of labor.

(6) The Tabun plant at Dyhernfurth ran at 75 per cent capacity in September and October and complained of shortages of methanol, ammonia and threaded plugs for shells and containers. Production dropped to 50 per cent in November and 30 per cent in December with additional shortage of sodium cyanide.

(7) The thoidiglycol mustard plant at Ammendorf ran at about 40 per cent of capacity because of a limited ethylene oxide allocation and was shut down practically completely during November and December. The plants at Huels and Gendorf were not operated on account of raw materials shortage, and the plant at Huels was crippled by an air raid.

(8) The direct process (Levinstein) mustard plant at Gendorf was operated at 40 per cent capacity in September and was then shut down because of chlorine

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shortage, and the available labor was diverted to construction of the enlarged plant.

(9) Practically no nitrogen mustard was made at Ammendorf on account of air raids on Ludwigshafen which stopped the flow of raw materials.

(10) Production of decontaminating materials was similarly limited by lack of raw materials and transportation difficulties.

v. Apparently, the Germans were afraid that the Russians would use gas and they built up large production capacity and fair-sized reserves for retaliatory purposes. Actually they produced at the rate of only about 10 to 12 per cent of their capacity. Their decision not to initiate the use of gas was dictated by Hitler. According to Gen Henrici, humanitarian considerations were responsible for the decision; others said it was not used because Germany had more to lose than to gain in a situation in which the Allies held superiority in the air and in the capacity to manufacture gas. Gen Henrici said that preparations had been made to fill rifle grenades with a liquid war gas known as Gewehr Flussigkeit Grenade.

5. Smoke Screen Materials

a. The main smoke agent used by the German army and navy and for the screening of industrial plants and military installations was Nebelsaure, a mixture of chlorsulfonic acid and sulfur trioxide. I.G. at Leverkusen developed an apparatus used exclusively for shore installations by the German navy for producing fogs from this mixture. The compsoition varied with the season of the year as follows:

	Summer	Winter
SO_3	50%	40%
$CI\ SO_3H$		

b. Leverkusen produced the smoke acid in quantities as follows:

Year	Tons	Year	Tons
1939	111	1943	6513
1940	0	1944	5400
1941	0	1945	155
1942	1811		

c. The production was greatly expanded during the war, and plants were constructed with capacities about as follows:

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POWDER EXPLOSIVES AND RELATED PRODUCTS

	Planned capacity for 1945 tons per month	Actual capacity end 1944 tons per month	
Leverkusen (not finished)	3,500	800	
Hoechst	2,500	1,500	xx
Ludwigshafen	1,500	800	x
Wolfen (new plant)	1,000	800	
Moosbierbaum	2,000	800	x
Leuna	300	300	
Fahlberg List, Madgeburg	2,400	2,400	
V. Heyden, Weissig	700	700	
Zellwelle Schwarza (not finished)	2,000	-	
Total	15,900 tons per month	8,100 tons per month	

x - bomb damage
xx - indirect bomb damage.

d. The enormous expansion in smoke acid production after 1941 is shown in Exhibit CI. From this Exhibit it will be seen that the bars are actual production up to and including May 1944, and predicted production from June on. The actual production from June 1944 to February 1945, is shown in red. As a result of bomb damage to Leverkusen, Leuna, and Moosbierbaum, the production actually decreased steadily after the bombing of chemical plants started, rather than increasing according to plan. The last planning figure of the Planungsamt on 2 March was only 800 tons per month.

e. The Germans were forced to take definite steps to insure maximum benefit from the limited and shrinking supply of smoke acid. Only those industrial plants and military installations of greatest importance were given this protection. As the Allied armies in the west advanced after the invasion, the boundary of the zone in which installations would be supplied with smoke acid was moved eastward correspondingly, for it was useless to furnish the acid unless the installation had sufficient forewarning of a raid to establish a smoke screen before the bombers arrived.

f. Various substitute and auxiliary smoke mixtures and furnaces for setting up smoke screens with them were developed. The following are some examples:

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55% Ammonium chloride
10% Hard pitch
30% Potassium chlorate
5% Sodium sulfate decahydrate

or 55% NH Cl.
30% $KCLO_3$
10% Bituminous coal powder
4% Water

g. Material was sieved through a 2 mm screen and mixed in a concrete mixer. It was packaged 25 kg in a waterproof paper bag and the bag had a burning time of about 10 minutes.

h. Fly ash mixtures were developed at Bitterfeld:

29% NH Cl)
29% $KCLO_3$) 5-10% water
42% Fly ash having about 30% C) added

or 42% NH_4Cl
42% KNO_3
16% Fly ash

i. And at Wintersahll A.G.:

54% NH_4Cl
27% KNO_3
19% Fly ash

j. The Leuna plant developed a furnace for incomplete combustion of residual oil to produce a dark smoke. Each furnace consumed 70 kg. of tar per hour. The furnace was heated with light oils to start the smoke. A letter from Dr. Neukirch of Gebechem to Dr. Ritter, dated 10 February 1945, indicated that development work was being done on the Langmuir oil-fog generator.

k. Late in 1944 it was decided that since there were so many urgent demands to repair damage and restore plants that it was impossible to do all such jobs, and since the smoke acid plant repair and construction could therefore be done only at the expense of active defensive weapons, that priority thereafter would be given to plants producing such active weapons as flak and fighter planes. This accounts in part for the rapid fall in smoke acid production and use in the closing months of the war.

l. Hexachlorethane was also manufactured for the usual smoke munitions (pots, grenades). Plants were located at:

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Zacherndorf	60	tons	per	month
Burghausen	50	"	"	"
Rheinfelden	55	"	"	"
Assig	550	"	"	"
Osternienburg	500	"	"	"
Bruekl	150	"	"	"
Schkopau	500	"	"	"
Trostberg	500	"	"	"
Hoechst	500	"	"	"

m. The following meager indications of production volume for hexachlorethane and titanium tetrachloride, another smoke agent, were found in the form of estimated chlorine requirements.

Smoke Agent	Estimated chlorine Requirements tons per month			
	3rd Quarter 1943	4th Quarter 1943	1st Quarter 1944	2nd Quarter 1944
Hexachlorethane	1,400	1,400	1,400	1,400
Titanium tetrachloride	90	90	90	90

n. In summarizing, it may be said that although deliberate attacks were not aimed at war gas production, those plants which were integrated with the large synthetic oil and rubber plants were destroyed or crippled by the air attacks directed at oil and rubber. The other plants were seriously limited by shortages of raw materials as an indirect effect of bombing of the large chemical plants.

o. Smoke acid production was similarly reduced progressively after May 1944 to perhaps 10 per cent of the normal by air attacks on large chemical and oil plants with which the smoke acid plants were associated. As a result, it was impossible to screen as many important facilities, thereby making further bombing easier.

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

Acardit	- Diphenylurea
Centralit I	- Diethyldiphenylurea
Centralit II	- Dimethyldiphenylurea
Di - DNB	- Dinitrobenzene
DNP	- Dinitrophenol
DNT	- Dinitrotoluene
Hexa	- Hexanitrodiphenylamine
Hexogen	- Cyclotrimethylenetrinitramine
NC	- Nitrocellulose
Ngl	- Nitroglycerin
Ptn, Penthryt, Nitropente	- Pentaerythritoltetranitrate
Tetra-Tetryl	- Trinitrophenylmethylnitramine
Guni	- Guanidin Nitrate
Nigu - G Salz	- Nitroguanidin
Pol-Powder	- Solvent-less Powder - Double base powder
Degn	- Dinitrodiglycol
P.H. Salt	- Ethylenediaminedinitrate ?
S.H. Salt	- Potassium salt of methyleneaminosulfonic acid
T-Stoff	- 82-85% Hydrogen Peroxide
B-Stoff	- Hydrazine Hydrate
Z-Stoff-C	- Calcium Permanganate
Z-Stoff-N	- Sodium Permanganate
K-Stoff	- Gas warfare material
Cherrystone (Kirschstein)	- V2 Flying Bombs

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A - GERMAN ORGANIZATION SCHEME FOR ERECTION AND OPERATION OF CHEMICAL WAR PLANTS (5 EXHIBITS)

A1- FINANCIAL STRUCTURE OF GERMAN EXPLOSIVES INDUSTRY BEFORE THE WAR

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POWDER, EXPLOSIVES AND RELATED PRODUCTS EXHIBIT A

Organization of the military armament in the "Oberkommando des Heeres (OKH) and in the "Heereswaffenamt" (OKH, WaA).

(Status at the beginning of 1945)

Remarks:

Chef H Rust u B D E - "Chef der Heeresrustung und Befehlshaber des Ersatzheeres".
(Chief of the Armament of the Army and High Commander of the Home Forces of the Army).

Until 20 July 1944 commanded by Generaloberst Fromm, then by Reichsfuhrer SS, represented by SS-Obergruppenfuhrer Juttner. In February 1945 the armament of the army was placed under the command of the "Chef Heeresstab beim OKW". (Chief of the Army-Staff in the High Command of the Military Forces) General Buhle.

AHA - "Allgemeines Heeresamt" (General Office of the Army). Organization of the Home Forcesof the Army. (Raising, training and reinforcement of troops).
Support of arms and ammunition to the front. Divided in several departments e.g. AHA/In 9 departments for smoke troops and anti-gas, or AHA/Sn inspection for medical service.

VA - "Heeresverwaltungsamt" (administration of the Army). Organization and supply of food and clothes for the Army.
Office for the administrative officials and the employees of the Army. Planning and construction of camps, barracks, shooting grounds, plants for finishing of ammunition.

WaA - "Heereswaffenamt" (Armament Office of the Army). Development testing, supply and transports of arms, materials and ammunition. Planning and construction of the industry needed therefore. Chemicals such as powder, explosives, gas, smoke and decontaminators are supplied by this office for the entire military forces (Army, Air Force, Navy).
The "WaA" is divided in different "Amtsgruppen" (groups), these groups being divided in several "Abteilungen" (departments).

WaZ - Central groups for organization of the WaA. Finances and contracts. Office for printed materials for the Army.

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Wa Pruf - Group for testing and development of arms, materials and ammunition E.G.

Wa Pruf 1: Department for ballistics and ammunition including powder and explosives.

Wa Pruf 9: Department for gas and gas-protection.

Wa F - Department for scientifical research.

Wa (Wu.G) - Group for supply of arms and materials for the Army.

Wa Mun - Group for supply of ammunition for the entire military forces.

Wa Chef Ing - Group for mechanical engineering. (Chemical engineering is in the competence of the group Wa Mun: powder and explosives being treated by the department Mun 3, all other chemicals by the department Mun 6.)

Wa Abn. - Group for receiving of arms, ammunition and materials.

One supplement

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Exhibit A-1 - Financial Structure of the German Powder and Explosives Industry (Quoted from British MEW Economic Survey of Germany, Section K, Armaments and Munitions.)

"The controlling influence in the German explosives industry is, without doubt, the Dynamit AG, with headquarters at Troisdorf. This large combine was formerly Alfred Nobel & Co, from which company the Dynamit organization has evolved by a series of amalgamations, agreements and purchases. The Dynamit AG, entered into an agreement with I. G. Farbenindustrie AG on August 9 1926, whereby the community of interests of the two companies is confirmed and the relative value of their share capital defined until 31 December 2024. The I. G. Farben guarantees to the Nobel shareholders one-half of the dividend paid on I. G. shares and has given them the right (after 1 January 1937) to require the exchange to their Nobel shares for I. G. shares in the proportion of 2:1. This agreement has placed the greater part of the German chemical and explosives industries under the control of what is virtually a single body.

Company	Capital (RM) x	Dynamit participation (percentage)
Lindener Zundhutchen und Patronenfabrik, Troisdorf	100,000	65
Kunstfaden GmbH, Troisdorf (plastics	200,000	100
Sprengstoff-Verkaufs-GmbH, Troisdorf (sales)	100,000	65
Rheinische Gummi-und Celluloidfabrik, Mannheim (plastics and rubber)	1,000,000	60
G. C. Dornheim AG, Berlin	500,000	97
J. F. Eisfeld Pulver-und Pyrotechnische Fabriken GmbH, Silberhutte (Anhalt)	600,000	65
Patronen-Zundhutchen-und Metallwarenfabrik GmbH, vormals Sellier und Bellot Schonebeck, Bad Salzemen	1,200,000	60
Rheinisch Westralische Sprengstoff AG, Nuremberg	100,000	100
Venditor Kunstoff Varkaufsgesellschaft GmbH, Troisdorf	20,000	100
Celluloid Verkaufsgesellschaft GmbH, Berlin(sales)	100,000	40
Gustav Genshow & Co AG, Berlin (cartridges)	1,000,000	50

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Company	Capital (RM) x	Dynamit participation (percentage)
Kola-Rottweil AG, Berlin (foreign for I.G. and DAG)	1,000,000	50
Pfalzische Pulverfabriken St. Ingbert GmbH, St Ingberg	800,000	65
Sprengstoff-und Zundschnurwerke, Gnashwitz	650,000	65

x) The figures given under capital are taken from the Dynamit AG report for 1938 and are entirely nominal, bearing no relation to the actual size of the companies. Rheinische Westfalische Sprengstoff AG, for example, had a capital of RM 14,160,000 as an independent concern.

"Second in importance among German explosives manufacturers is the Westfalische Anhaltische Sprengstoff AG (WAS AG) and its subsidiaries. This combine, in addition to the manufacture of explosives and intermediates, also manufactures chemicals - particularly sulphuric acid, glycercol and super-phosphates, collodion wool (nitro-cellulose staple fibres), celluloid, etc.

"The parent company owns factories at Reinsdorf, Goswig (Anhalt), Sythen, Elsnig and Oranienburg. It has a majority interest in the following concerns:

Company	Capital (RM)
H. A. Meyer und Riemann Chemische Werke A G, Hannover	1,000,000
Zunderwerke Ernst Brunn K.G., Krefeld-Lind	unknown
Sprengstoff-Verkaufs GmbH, Cologne) sales	100,000
Celluloid-Verkaufs-GmbH, Berlin)	100,000
"Union" Fabrik Chemische Produkte, Stettin	6,150,000
Gesellschaft fur Chemische Forschung und Verwaltung GmbH, Berlin	1,000,000
Chemische Studiengesellschaft Uniwape GmbH, Berlin	unknown
Cueno-Werke AG, Hamburg	5,600,000

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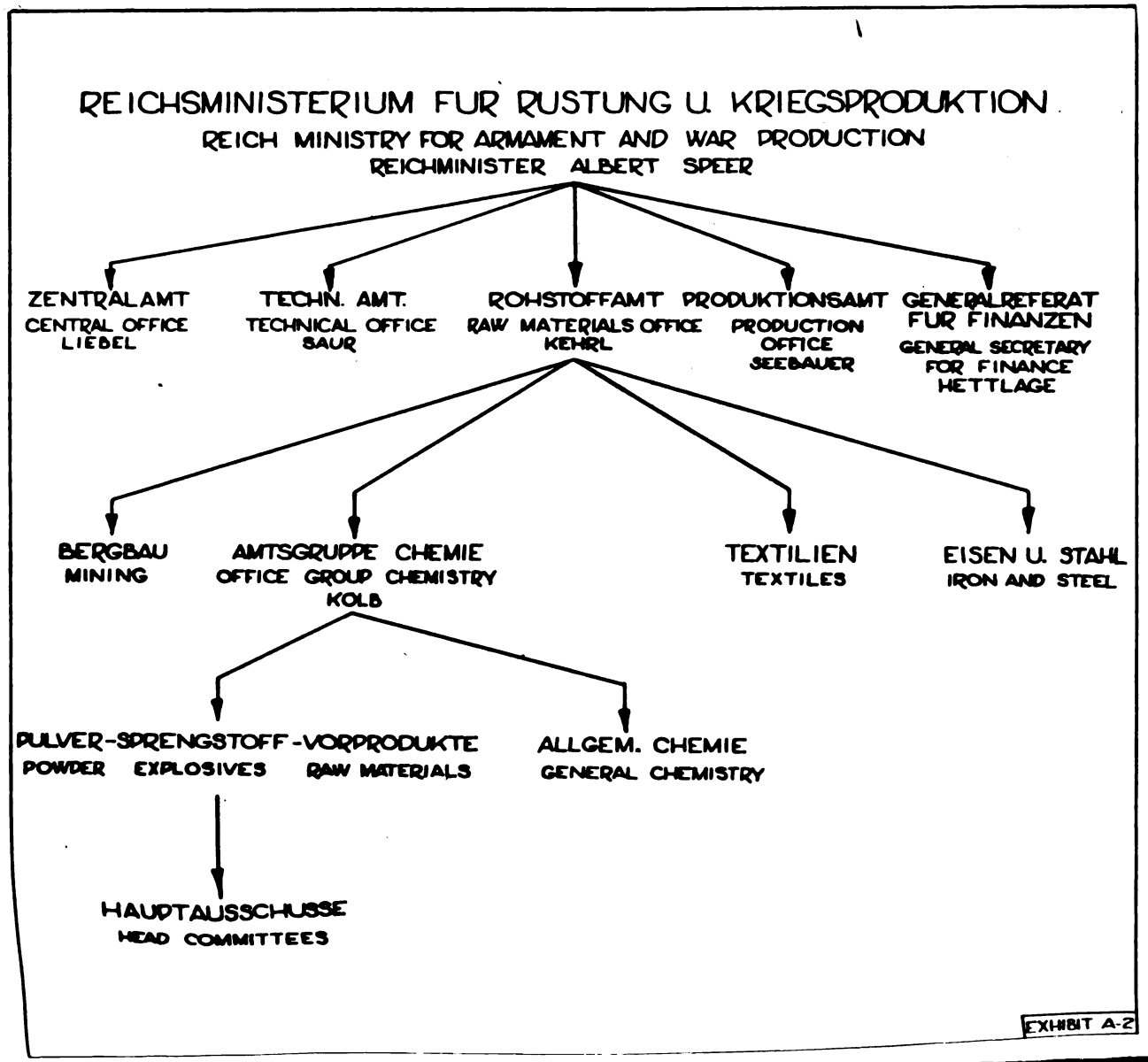

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...mical war plants.

Abb.:

Government organization
administration and distribution of public means
financial control of given means
orders for erection of plants and for production (quantities)

Private industry
had to develop new processes
to chose locations best suited
to erect plants on the cheapest way
to rationalize production by disposing of specialized personnel, skilled men and technical experience (incl. patents) etc.

Part-financing of:
Deg... gasoline, oil, pyrites,
Bind... and other primary
Gebäu... layer materials. Includes
Schien... cost of tank-cars etc.

...rection of plants for:
...tric acid, sulfur,
...luene etc, if rentability
...r production could not
...e expected. Includes
...cost of tank-cars etc.

Wa...

Wo...

D...

I.G. Farben, Ruhrchemie Holten, Kalichemie Stickstoffwerke Königshütte and Linz.
and various other firms, leased plants, erected by public means given and controlled by Wifo, for production of:
Nitric acid: Döberitz, Embsen, Langelsheim, Piesteritz, Wolfen-Farben, Holten, Sondershausen, Linz, Königshütte, Heydebreck etc.
Toluene: Pölitz, Holten, Waldenburg, Ludwigshafen.
Sulfur: Niedersachswerfen, Schoppinitz
Chloroethyle, Ethylenebromide, Strontianite.

I...

Constant pressure and admonishing to IG.-Farben (and probably other firms) to erect similar plants by own means led only to relatively small expansions.
E.g. Oppau, Höchst, Leuna. Partially subsidies were given in such cases by Wifo. (technical term in J.G. „verlorener Zuschuss") (cost subsidy).

I...

EXHIBIT A-1

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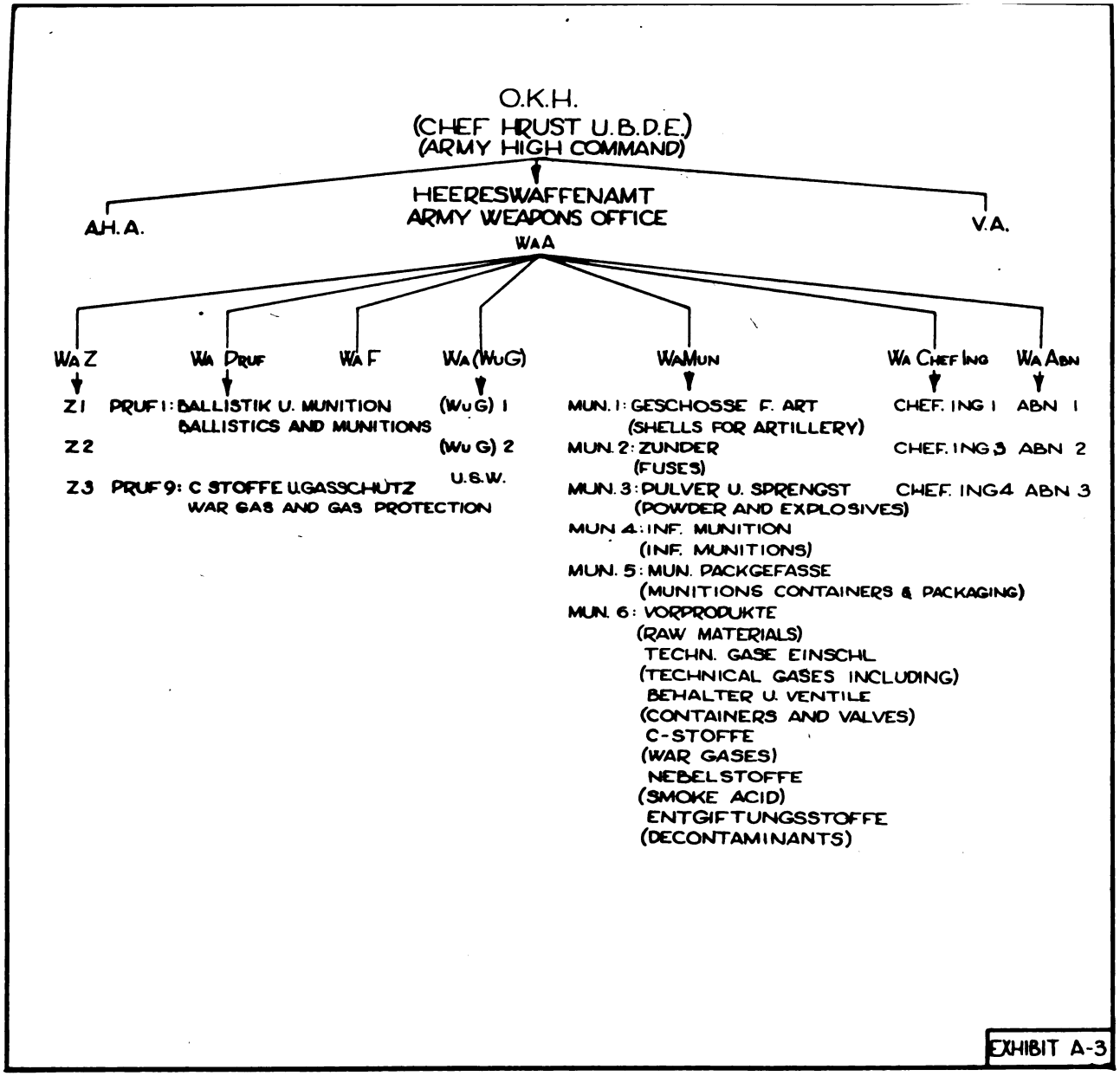

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B - ORGANIZATION OF HEAD COMMITTEE FOR POWER - EXPLOSIVES

B1 - STEPS IN EARLY PLANNING FOR WAR (TRANSLATION OF CAPTURED GERMAN DOCUMENTS)

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POWDER, EXPLOSIVES AND RELATED PRODUCTS EXHIBIT B

The W.A.S.A.G. combine also has considerable holdings in the following firms, some of which are controlled jointly by W.A.S.A.G. and the Dynamit A.G.

Company	Capital (RM) x)	W.A.S.A.G. participation (Percentage)
Koln-Rottweil AG	1,000,000	50 per cent. (An agreement exists between this company and Dynamit guaranteeing Koln-Rottweil interest)
Rheinische Gummi-und Celluloid-Warenfabrik, Mannheim	1,000,000	40 per cent. (Dynamit AG have a 60 per cent interest).
J.S. Eisfeld GmbH Silberahutte	600,000	Unknown (Dynamit have a 65 per cent interest).
Pfalzische Pulverfabriken St. Ingbert GmbH, St. Ingbert	800,000	Unknown
Sprengstoff-und Zundschnurwerke Gnaschwitz AG, Gnaschwitz	650,000	25 per cent, (Dynamit AG have a 65 per cent participation)
Gebr. Martin GmbH, St. Ingbert	800,000	25
Sprengstoff und Pyrotechnische Fabriken (vermals Lechfeld und Depyfag GmbH) Neumarkt	80,000	25

x) The figures for the capital of WASAG subsidiaries are again entirely nominal. Koln-Rottweil had a capital of RM 21,000,000 as an independent concern prior to the conclusion of the agreement with Dynamit AG.

Other units were Wolff and Co AG, at Walsroder, an I.G. Farben-industrie subsidiary with capital RM 2,380,000 and Lignose, GmbH, with capital RM 3,100,000.

Note:

This quotation may contain some inaccuracies. For example the Schonebeck plant is known to belong to Lignose instead of DAG.

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EXHIBIT B

ORGANIZATION OF THE GERMAN EXPLOSIVES INDUSTRY
MARCH 1943

Hauptausschuss Pulver u. Sprengstoff
Leiter: Gen. Dir. Dr. Sarrazin
Berlin W9, Linkstrasse 25
Ferngespr. 219646 Stadtgespr. 219391
Fernschreiber 01 14 28
Arb. Buro: Leiter Dir. Dr. Richter
Berlin W9, Linkstrasse 25
Ferngespr. 219646 Stadtgespr 219391
Fernschreiber 01 14 28
Fertigung u. Abnahme: Maj.z.V. von Malsen

Arbeitseinsatz :Oberstlt. S.D. Garke
Techn.Angelegenh. :Dir.Dipl.Ing. Ehnimb
Leistungssteigerung :Obering. Hofmann
Saurefragen :Dr. Rohrlich
Kohle u. Transport :Dr. Ott

Sonderausschuss Pulver
Leiter: Dipl.Ing.Gunther Wolff
Walsrode u.Hannover; tel.251
Fernschr. 02 374
Arb.Buro: Leiter Carl Hoffmann
Wolff u.Co.K.G.a.A.,
Verbing.Stelle Berlin
Berlin W8,Friedrichstr.194/199
Telefon 11 10 64

Arb.Ausschuss 1	Arb.Ausschuss 2
Dr. Walter Troisdorff	Dir.Dr.Richter Berlin

Arb.Ausschuss 3	Arb.Ausschuss 4
Dir.Dr.Wunder TSC Torgelow	Dir. Holz DAG-Krummel

Arb.Ausschuss 5
Dr. Petzel I.G. Eisfeld-Kunig

Sonderausschuss Sprengstoff
Leiter: Dir.Dipl.Ing.Schindler
Troisdorf Baz.Koln;Tel Koln 10281
Fernschr. 03845
Arb.Buro:Leiter:Prof.H.R.Dufour
Dynamit M.G.Buro Siegmundshof
Berlin N.W.87 Siegmundshof 17:
Tel. 395011:
Fernschr. 01 1486

Arb.Ausschuss 1	Arb.Ausschuss 2
Dir.Dr.Neale DAG-Krummel	Dipl.Ing.Brunne WSag Reinsdorf

Arb.Ausschuss 3	Arb.Ausschuss 4
Dr. Mennicken DAG-Troisdorf	Dir. Habbel

Arb.Ausschuss 5	Arb.Ausschuss 6
Dr. V. Nagel I.G.Ludwigshafen	Ob.Ing.Haueschen DAG Bad Sachsa

Sonderausschuss "C"
Leiter: Dir.Dr. O.Ambros
Ludwigshafen;Tel.6496
Fernschr. 03478
Arb.Buro:Leiter Dr.Pfaundler
Berlin SW 68,Kochstr. 73
Telefon 120021
Fernschr. 01 11 70

Arb.Ausschuss 1	Arb.Ausschuss 2

Arb.Ausschuss 3	Arb.Ausschuss 4

XVII	Wien,Oberdon,Nied,Don	Dir.Dr.Hoenig,Blumau
XVIII	Salzb.Tir-Voralb.Steierm	Karnt.Dr.Zwicknagl.St.Lambrecht
XX	Danzig	DirDr.Kampf, Bromberg
XXI	Wartheland	
	Protekt. Prag	Maj.Dr.Steindorff,Semtin
	Generalg. Krakau	

Bezirksbeauftragte:

Wehrkreis:	—Gau:	Beauftragter:
II	Pommern	Dir Dr Wunder,Torgelow
"	Mechlenburg	Dir Dr Wunder,Torgelow
III	Berl-Brandenb.	Dir Dr Richter, Berlin
IV	Sachsen	Dir Heilmann,Graschwitz
"	Sudetenland	Dir Hessinger, Hertine
V	Wurttemberg	Dir Dr Osternurg,Rottweil
"	Baden-Elsass	Dr Liebich, Rheinfelden
VI	Westf-sud u nord	Dir Dr Haug. Sythen
"	Essen.Dusseld. Koln, Aachen	Dir Habbel. Troisdorf
VII	Schwaben,Obern	Dir Dip Ing Bender,Munchen
VIII	Niederschlesien	Dr Breucker, Breslau
"	Oberschleisien	Dr Simon, Kattowitz
IX	Kurhessen	Dir Dr Praetorius
"	Thuringen	Dir Dr Praetorius
X	Schleswig-Holst	Dir Dr Neale, Krummel
"	Hamburg	Dir Dr Neale, Krummel
"	Osthannov-Luneb	Dipl Ing Gunther Wolff Walsrode u. Han.
XI	Westfms Sud Han Braunschw	Dir Dr Caspers, Clausthal
"	Magdeb-Anhalt Halle-Merseb	Dir Maj. Fromm Reinsdorf
XII	Hess-Nass,Mosell Wasm	Dr Ahrhard, Ludwigshafen
XIII	Franken,Mainfr. Bayreuth	Dr Frank Koll, Neumarkt Oberpf

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I Dr. R./G. Berlin, 21 Apr. 1942.

Remarks on the Development of the Gunpowder, Explosives, Poison Gas and Raw Materials Program Since 1937

I. Development of the Objective
(see chart) (missing)

1. Early in 1937 the armed forces believed that as a result of a shortage of raw materials the supply would be limited to

3,300 tons of gunpowder per month
9,000 " " explosives " "
3,000 " " poison gas " "

At that time the office for German raw materials for chemical processes and fabrications had drafted a program including a raw materials plan for

19,000 tons of gunpowder per month
15,000 " " high explosives per month
(corresponding to 22,500 tons of extended explosives per month)

The Hindenburg Program of World War I was used as a basis of comparison.

2. In April 1938 the Reich office for economic expansion drafted, in the course of a detailed investigation of possible raw material sources, a program for

18,000 tons of gunpowder per month
(including 12,000 tons of Pol per month)
17,000 " " high explosives per month
(including 9,900 tons of Tri per month)
25,000 " " total extended explosives per month plus
10,000 " " ammonal per month
35,000 " per month.

Attention is called to the fact that the raw materials required come exclusively from domestic sources.

"The demand may be filled even in case of a greatly increased demand for gunpowder and explosives."

3. "Proposal for an accelerated production plan, dated 30 June 1938." This expansion plan is included in the "Karinhall" Plan" dated 12 July 1938.

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Planning:

18,000 tons of gunpowder per month
(14,100 tons of Pol per month
4,000 tons of NC-powder)
17,100 tons of high explosives per month
(including 9,200 tons of Tri per month
4,000 tons of hexogen per month)
25,000 tons of explosives per month (excluding ammonal)

4. 13 August 1938. "Summary of the expansion possibilities within the German chemical economy."

The expansion after 1942 insofar as it is possible, in view of the raw materials and technical situation (future continuation of the program) is outlined.

"The production of raw materials and auxiliary products may be increased at the rate of a future expansion plan."

It is suggested that the following outputs may be achieved:

	1944	1946
Gunpowder	30,000 tons per month	36,000 tons per month
High explosives	26,000 " " "	30,000 " " "
Extended explosives	36,000 " " "	45,000 " " "

5. The accelerated plan, dated 13 August 1938, provided for:

18,100 tons of gunpowder per month
18,600 " " high explosives per month

- 28,000 tons of extended explosives per month
7,800 " " poison gas per month.

6. 27 February 1939. "Study estimating the objective of the German gunpowder and explosives expansion."

Lower limits:
34,000 tons of gunpowder per month
40,000 " " extended explosives per month

Upper limits:
55,000 tons of gunpowder per month
60,000 tons of extended explosives per month

(These figures correspond to an army staff demand which was under discussion at that time.)

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"Any step designed to increase the gunpowder and explosives capacity will be proper for many years."

"It may be stated in general that the German chemical industry will be able, from a technical and process point of view, to deliver the raw materials and that the gunpowder and explosive industry will be able to cope with the problem."

7. The working report given by the GB-Chem. to the General Council states that the current expansion plan "represents the minimum requirements for guaranteeing the defensive strength of the nation in the field of gunpowder and explosives."

8. In August 1939 the possibility of a large scale poison gas program on the basis of coke oven gas and hydrogenation off-gas has been proposed for 22,000 tons of poison gas per month.

9. September 1939. On the basis of the consumption figures of the Polish campaign, it is suggested that "the explosives production be expanded far beyond the contemplated goal."

Proposals for explosive mixtures have been made.

10. In November 1939 the Army High Command requested a "supplemental mobilization plan" as follows:

20,000	tons	of	gunpowder per month
27,000	"	"	high explosives per month
20,000	"	"	extenders per month
12,000	"	"	ammonal per month
79,000	"	"	per month total
20,000	"	"	poison gas per month.

11. Adjustment of the new supplemental mobilization demand to the so-called "Orange-Plan" dated 25 November 1939.

20,000	tons	of	gunpowder per month
62,500	"	"	total extended explosives per month
15,000	"	"	poison gas per month.

12. The high requirements were dept up only for a short time. They were reduced by the Army High Command prior to the French campaign on 8 April and 20 April 1940.

On the basis of a new Fuhrer demand the maximum requirement was fixed as follows:

14,000	tons	of	gunpowder per month
20,000	"	"	high explosives per month
30,000	"	"	extended explosives per month.

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13. On 1 July 1940 the expansion goal was fixed by all Government offices in co-operation, on the basis of consumption of ammunition in the West as follows:

16,000 tons of gunpowder per month
21,000 " " high explosives per month
32,000 " " extended explosives per month (including ammonal)

All construction projects exceeding these capacities have been completely cancelled.

The armed forces do not at present contemplate to put in operation the gunpowder and explosives plants now being completed, with the exception of bomb-and shell-charging stations.

14. September 1940. As a result of the gunpowder consumption of the anti-aircraft artillery the production of Pc.1 powder has picked up.

15. The expansion goals remain practically unchanged even during the Russian campaign in 1941.

On 6 November 1941 the planning, including all raw materials, was again summarized and newly outlined (accelerated plan, status as of September 1941)

16,600 tons of gunpowder per month (including 13,600 tons of Pol per month)
19,600 tons of high explosives per month (including 14,300 Tri 2,700 Hexogen), plus
16,000 tons of diluents per month
35,600 tons of extenders explosives per month
9,400 tons of poison gas per month (including 5,500 tons of L)

Attention is called to the larger outputs of the plants in the case of Pol powder and Tri and to the necessity of increasing the output of diglycol and toluene as raw materials in accordance with a full utilization of the planned capacities.

16. From November 1941 on, the Army High Command rationed technical nitrogen for the gunpowder and explosives production in favor of fertilizer supply for agriculture and reduced the industrial allotments below the plan figures for the period from 1 November 1941 to 1 June 1942.

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17. 26 March 1942. Minister Speer requests on the basis of new ammunition demands of the Fuhrer a "permanent maximum output which exceeds the figures of the planning, up to date.

16,000 tons of Pol powder per month
18,400 " " Tri per month should be reached if possible.

Continuation of the construction of the toluene plant Holten and new construction of the diglycol plant expansion Gendorf and Auschwitz are required for this purpose.

The goal of the planning from that time on is:

19,100 tons of gunpowder per month
(including 16,100 tons of Pol per month)
23,300 tons of high explosives per month
(of this 18,000 tons of Tri
3,200 tons of hexogen per month)
35,000 tons of extended explosives per month.

18. 15 April 1942. On the basis of ammunition demands of the Fuhrer the Army High Command -- Armaments office -- has calculated new gunpowder and explosives requirements as follows:

33,000 tons of gunpowder per month (including 30,000 tons of Pol)
31,000 tons of high explosives per month (including 24,000 tons of Tri and 4,800 tons of Hexogen per month)
50,000 tons of total extended explosives per month.

The feasibility of realizing these new requirements in being investigated. The expansion must be completed by the end of 1944 or the beginning of 1945 (see item 4).

Difficulties in the Execution (see chart)

1. August 1938. "The execution of the accelerated plan is possible only as far as special war powers are given to the office responsible for the execution."

Shipments should have priority over all other orders.

2. On 30 August 1938, the iron demanded will be made available. A special priority number Gs will be issued. However, no priority higher than that of all other priority numbers is established. It is merely put on an equal basis with the priority numbers of the armed forces. The Army High Command (armament office) refuses expressly to put Gs orders ahead of XP orders. (XP - fortifications in the West.)

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3. September/October 1938. Only 50 per cent of the needed cement was supplied. GB-Chem calls attention to the danger to the scheduled dates.

4. October 1938. "The withdrawal of the XP designation constitutes a serious danger to the accelerated plan and would make its execution impossible within the time set."

It is requested that the orders be given priorities ahead of all domestic orders.

5. December 1938. The withdrawal of the XP priority number which was replaced by the new priority number Gs only as recently as the middle of December has caused a delay of three months.

6. Steel reduction by 30 per cent through the armed forces. (pencil note 7 January 1939)

GB-Chem sends to all offices involved a memorandum with charts calling attention to the impending delay of six to nine months.

"The Hindenburg Program which took neither bombs nor anti-aircraft ammunition into consideration may serve at best as a starting point for the filling of the demand."

"For this additional reason any delay in the accelerated plan is unbearable, particularly because it must be expected that the English and French capacities will now be likewise considerably expanded."

7. An emphatic demand for steel of the Plenipotentiary for Iron and Steel Economy was answered on 16 January 1939 as follows:

"The fact that the armed forces make available to you only 65% of the amount of iron applied for, shows that the armed forces consider the execution of the gunpowder and explosives program over a longer period of time than contemplated by you as being justified in view of the scope of the problems to be solved by the armed forces."

8. Greatest difficulties arose in the allocation of lumber for the accelerated plan in March, April and May 1939. Only 10 per cent was alloted. Other offices being unable to help, direct negotiations were had with the Reich forest office and the Reich office for lumber and the difficulties were removed.

The allocation of structural steel during this time was utterly insufficient (only 60 per cent). General Keitel was specifically informed of the situation.

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9. The "simplified construction method" is urgently requested by the GB-Chem from the armament office because of the increasing difficulties with regard to construction materials. However, these proposals are not accepted.

10. GB-Chem contacted Todt in May 1939 in order to rush the accelerated plan. Dr. Todt stated that the armed forces were not interested in giving the accelerated plan priority over other plans of equal importance to the armed forces.

11. Repeated reduction of the iron rations by 25 per cent started July 1939. As a result, the expansion had only about 50 per cent of the speed originally contemplated. GB-Chem sends to all offices involved a memorandum with charts indicating delays of one year and more.

The memorandum shows clearly that a repeated shift of the expansion goal of the accelerated plan as a result of a further reduction of the iron rations is unbearable, particularly because it is to be expected that a substantial expansion of this important war economy sector will take place in England, France, etc in the near future."

12. The summary of the gunpowder -- explosives -- raw materials planning dated July 1939, shows the delays which made it impossible to reach the expansion goals of the accelerated plan prior to the end of 1941 or the beginning of 1942.

13. In November 1940 on, the iron ration was greatly increased on the basis of a discussion with Field Marshall Goring on 28 November 1939.

14. The intervention of the Plenipotentiary for Iron and Steel Economy is requested because of the serious difficulties in the supply of the maintenance and replacement demand of the current gunpowder and explosives industry.

15. Serious difficulties arose in the field of allocations of common metals for the accelerated plan. The bureaucratic and tardy handling of the allocation precedure causes delays at the Army High Command (armament office). An offer by the GB-Chem to take over the allocation of common metals remains unheeded.

15. Up to February 1940, all construction projects of the accelerated plan were in the urgency stage II. Because of new ammunition demands, the GB-Chem asked the Reich Marshall on 31 January 1941 that he place the accelerated plan in stage I. This was done for 4/5 of the plan.

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17. April 1940. Withdrawal of manpower from the gunpowder and explosives plants causes serious difficulties.

18. The allocation of iron for the accelerated plan drops again considerably after the campaign in the West. The Army High Command is, on the basis of the supplies situation, of the opinion that the time schedule of the projects of the accelerated plan need not be considered of paramount importance.

19. March 1941. The creation of the urgency stage 0 of the GB-construction results in additional difficulties in the construction of the plants.

20. In the middle of 1941 increasing difficulties arise from the withdrawal of manpower as well as in the allocation of concrete and motor fuel. Transportation is regulated.

21. At the end of 1941, the expansion is restricted through GB-Construction by a reduction of the construction volume in accordance with the determination of a number of plants is postponed. However, the construction of raw materials plants is not affected by the postponement.

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EFFECTIVE PRODUCTION CAPACITY REACHED AT END OF YEAR
TABLE AND GRAPH

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EXHIBIT C I

SMOKE-ACID PRODUCTION
IN TONS OF SMOKE-ACID PER MONTH

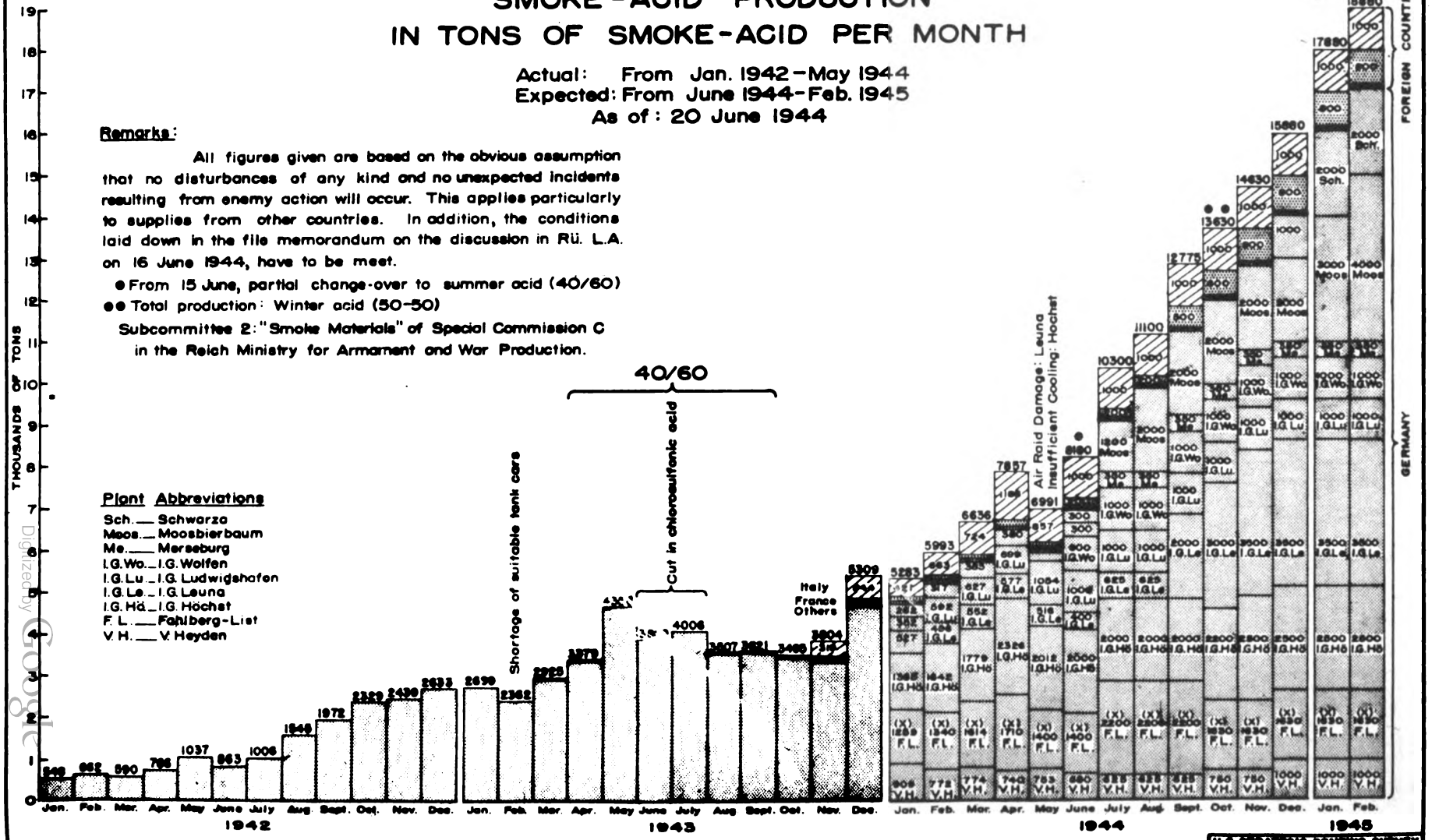
Actual: From Jan. 1942 – May 1944
Expected: From June 1944 – Feb. 1945
As of: 20 June 1944

Remarks:

All figures given are based on the obvious assumption that no disturbances of any kind and no unexpected incidents resulting from enemy action will occur. This applies particularly to supplies from other countries. In addition, the conditions laid down in the file memorandum on the discussion in RÜ. L.A. on 16 June 1944, have to be meet.

● From 15 June, partial change-over to summer acid (40/60)
●● Total production: Winter acid (50-50)

Subcommittee 2: "Smoke Materials" of Special Commission C in the Reich Ministry for Armament and War Production.



Plant Abbreviations

Sch. — Schwarza
Moos. — Moosbierbaum
Me. — Merseburg
I.G.Wo. — I.G. Wolfen
I.G.Lu. — I.G. Ludwigshafen
I.G.Le. — I.G. Leuna
I.G.Hö. — I.G. Höchst
F.L. — Fahlberg-List
V.H. — V. Heyden

(x) Includes the chlorosulfonic acid stored at present by Ludwigshafen at Fahlberg List. (For the months of June-Sept also that stored by von Heyden)

U.S. STRATEGIC BOMBING SURVEY

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EFFECTIVE PRODUCTION CAPACITY

REACHED AT THE END OF THE YEAR IN THOUSANDS OF TONS PER MONTH

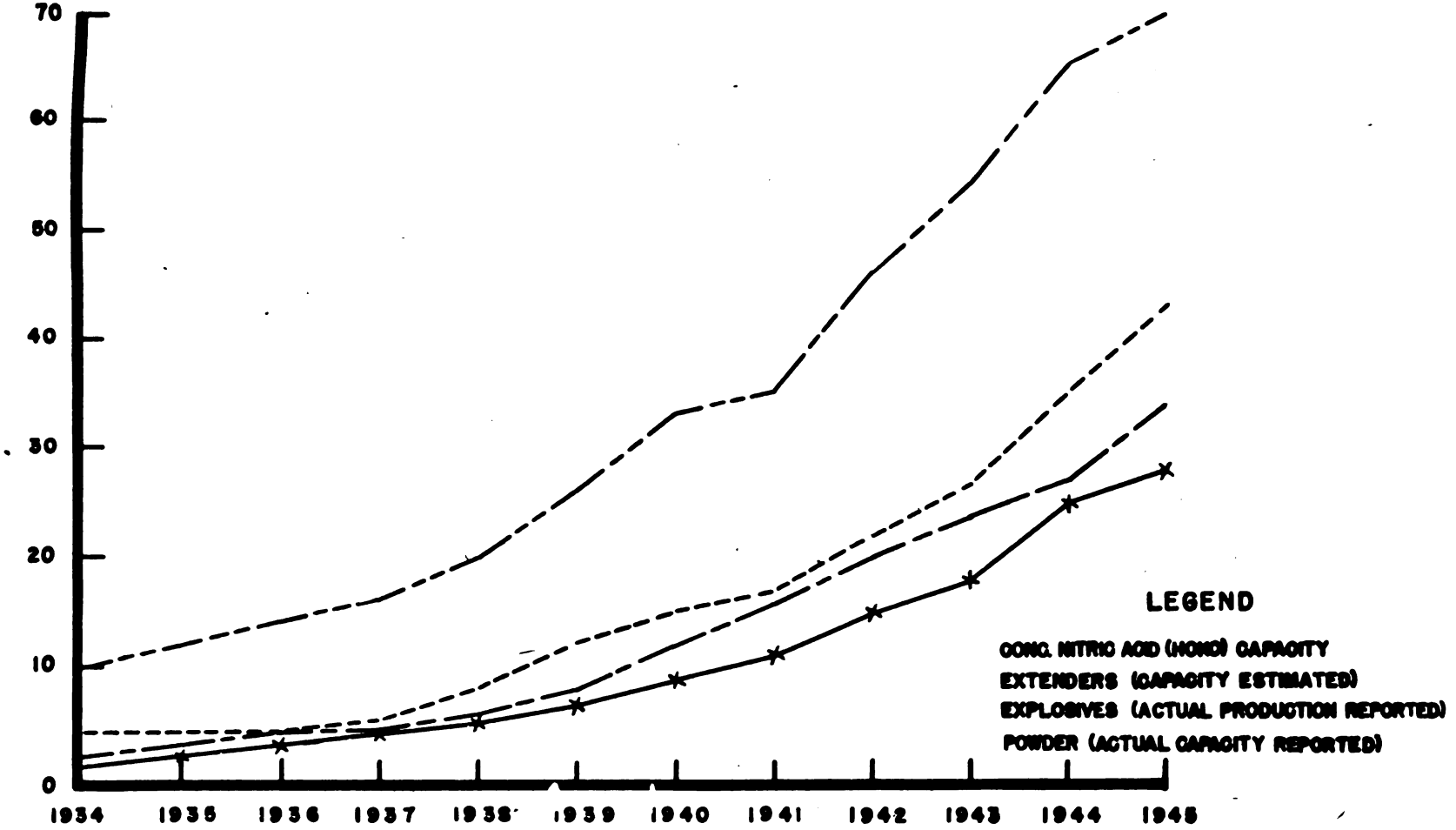

EXHIBIT C-3

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GERMAN POWDER PLANTS - TABLE AND MAP CHART

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

EXHIBIT D

Plants for Production of Powders

Capacity metric tons per month

No	Plant and location	Name of firm	Dec 1939 Reached	Dec 1939 Planned ø	Sep 1944 Reached	Sep 1944 Planned ø
1	Reinsdorf (Wittenberg-Elbe R)	Wasag	1,470	1,470	1,000	1,560
2	Bomlitz/Walsrode (Hannover)	Wolff a. Co	1,070	1,620	2,290	2,290
3	Moschwog (Magdeburg)	Wasag	730	730	775	775
4	Klietz (Magdeburg)	Wasag	1,100	1,100	1,900	1,900
5	Dueneberg (Hamburg)	DAG	1,100	1,850	3,000	3,000
6	Targelow (Stettin)	Wasag	1,000	1,000	1,830	1,830
7	Rottweil (Stuttgart)	DAG	230	230	330	330
8	Hasloch (Main-River)	Miscell. firms	70	70	90	90
9	Hohensanten (Brandenburg	Wasag	-	1,080	600	600
10	Kraiburg (Munich)	Wasag	70	1,220	1,640	1,640
11	Forst (Frankfort-Oder)	Wasag	-	1,225	1,560	1,560
12	Droetz (Frankfort-Oder)	Wasag	-	1,225	1,100	1,100
13	Liebenau (Hannover)	Wolff a. Co	-	2,000	1,560	1,590
14	Deerverden (Hannover)	Wolff a. Co	-	875	600	980
15	Ebenhausen (Munich)	DAG	-	470	500	950
16	Bromberg (Posen)	DAG	-	1,500	1,470	2,320
17	Kaufbeuren (Munich)	DAG	-	570	350	500
18	Ettringen (Lake Kenstanz)	DAG	-	400	-	-
19	Oderberg (Frankfort-Oder)	Wasag	-	-	1,460	1,460
20	Semtin (Prague)	Explosia-Prague	-	-	690	690
21	Blumau (Austria)	DAG	-	-	160	160
22	Christinastadt (Frankfort-Oder)	DAG	-	-	-	650
23	Ueckermuende (Stettin)	DAG	-	-	-	250
		TOTAL:	6,840	18,635	22,935	26,195

ø means the final capacity planned in Dec 1939 or Sep 1944, mostly to be reached years later - 2 -

Wasag - Westfaelisch-Anhaltische Sprengstoff AG)

DAG - Dynamit AG verm. Alfred Nobel) and subsidiary companies

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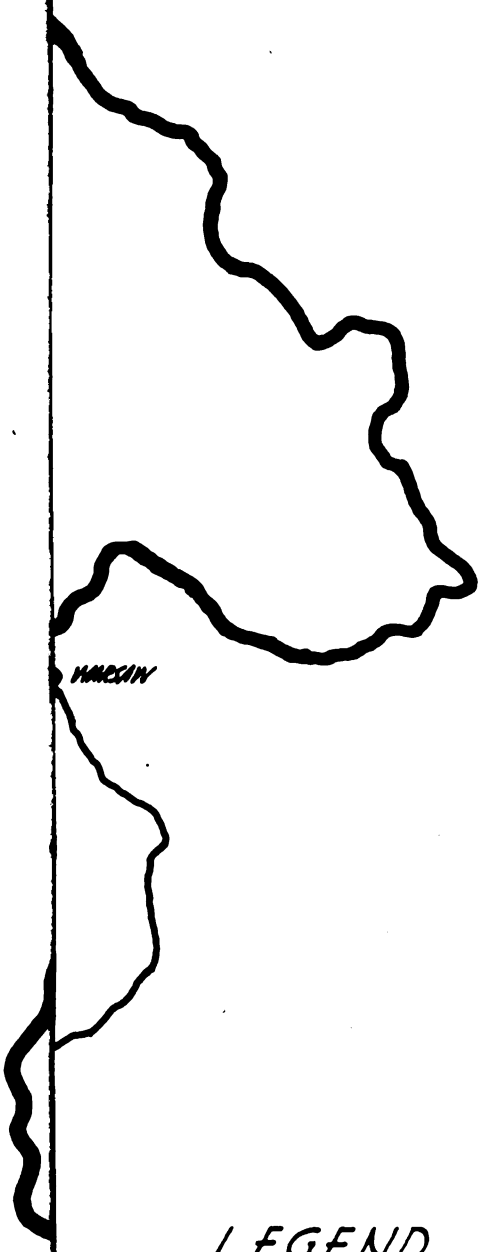

LEGEND

ACTUAL CAPACITY AS OF DEC., 1939

" " " " SEPT., 1944

FIGURES ARE IN METRIC TONS PER MONTH

POWDER PLANTS

TED CAPACITY AS OF DEC., 1939 & SEPT., 1944)

EXHIBIT D

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GERMAN EXPLOSIVES PLANTS - TABLE AND MAP CHART

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POWDER, EXPLOSIVES AND RELATED PRODUCTS EXHIBIT E

Plants for Production of Explosives

Capacity metric tons per month

No	Plant and location	Name of firm	Dec 1939 Reached	Dec 1939 Planned ø	Sep 1944 Reached	Sep 1944 Planned ø
1	Krummel (Hamburg)	DAG	1,288	1,850	2,800	2,950
2	Clausthal (Harts-Mountains)	DAG	1,100	1,600	2,800	2,800
3	Hassisch-Lichtenau (Kassel	DAG	1,250	1,750	3,500	3,895
4	Domitz (Luneburg)	DAG	1,025	1,025	1,200	1,325
5	Schlebusch (Cologne)	DAG	800	800	2,300	2,600
6	Elsnig (Wittenberg-Elbe R)	Wasag	1,215	1,315	2,600	4,225
7	Schonebeck (Magdeburg)	Lignese	650	650	400	900
8	Ludwigshafen (Rhine)	IG Farben	15	120	100	100
9	Semtin (Prague)	Explosia-Prague	225	175	400	800
10	Rottweil (Stuttgart)	DAG	15	15	-	-
11	Bobingen (Augsburg)	DAG	100	500	300	400
12	Reinsdorf (Wittenberg-Elbe R)	Wasag	100	225	350	350
13	Troisdorf (Cologne)	DAG	35	35	80	125
14	Wolfen (Bitterfeld	IG Farben	35	35	-	-
15	Allendorf (Marburg)	DAG	-	3,550	5,000	6,500
16	Malchow (Mecklenburg)	DAG	-	550	600	600
17	Wolfratshausen (Munich)	DAG	-	550	600	750
18	Doberitz (Berlin)	DAG	-	500	600	600
19	Cusen (Brandeburg)	DAG	-	900	1,300	1,300
20	Bromberg (Posen)	DAG	-	3,200	1,200	1,200
21	Christianstadt (Frankfort-Oder)	DAG	-	1,000	1,700	2,700
22	Grunberg and other projects without definite location	-	-	3,700	-	-
23	Ueckermunde (Stettin)	DAG	-	125	-	-
24	Dragaha (Hamburg)	DAG	-	-	1,100	1,100
25	Herreswald (Marburg)	Wasag	-	-	400	400
			7,853	24,170	29,330	35,620

ø means the final capacity planned in Dec 1939 or Sep 1944, mostly to be reached years later.
Wasag = Westfalisch-Anhaltische Sprengstoff AG
DAG = Dynamit-AG Vorm. Alfred Nobel

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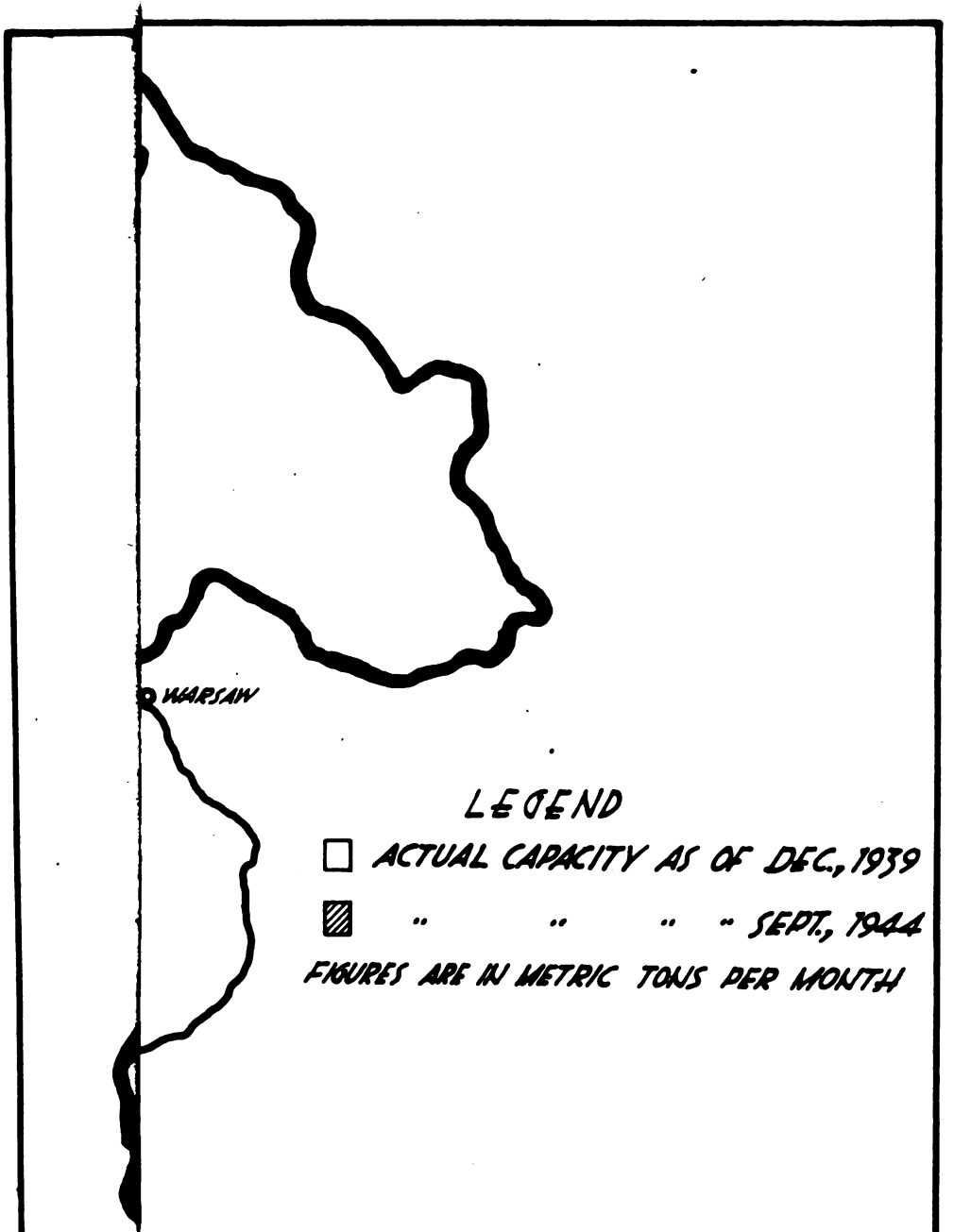

EXPLOSIVE PLANTS

FTED CAPACITY AS OF DEC., 1939 AND SEPT., 1944)

EXHIBIT E

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PLANTS FOR PRODUCTION OF EXTENDERS FOR EXPLOSIVES

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POWDER, EXPLOSIVES AND RELATED PRODUCTS EXHIBIT F

Plants for Production of Extenders for Explosives

Capacity metric tons per month

No	Plant and Location	Firm	Dec 1939 Reached	Dec 1939 Planned	Sep 1944 Reached	Sep 1944 Planned
	A) Ammonium Nitrate					
1	Wolfen/Bitterfeld	I. G. Farben	10,000	10,000	12,000	12,000
2	Piesteritz (Wittenberg -Elbe River)	Bayer Sticket W.	-	8,000	7,000	7,000
3	Leuna (Halle)	I. G. Farben	-	5,000	4,000	4,000
4	Hibernia (Ruhr)	Hibernia AG	-	1,800	1,000	2,000
5	Holten (Ruhr)	Ruhrchemie AG	-	2,000	2,500	3,300
6	Konigshutte (Upper Silesia)	Oberschles. Stick-stoffwerke AG	-	1,000	1,500	1,500
7	Cologne-Kalk	Chem.Fabr. Kalk	750	1,500	2,000	2,000
8	Linz (Austria)	Stickstoffw. Ostmark	-	3,200	-	2,500
		TOTAL:	10,750	32,500	30,000	34,300
	B) Dinitrobenzol					
9	Hochst (Main)	I. G. Farben	-	550	650	650
10	Leverkusen (Cologne)	I. G. Farben	-	1,050	700	700
11	Wolfen (Bitterfeld)	I. G. Farben	-	650	400	500
12	Bromberg (Posen)	DAG	-	2,000	450	450
13	Griesheim (Frankfort)	I. G. Farben	-	850	850	1,150
14	Offenbach-Mainkur	I. G. Farben	-	1,000	-	-
		TOTAL.	-	6,100	3,050	3,450
	C) M.A.N -Salt plus tetra-salt plus myrol øø					
15	Christianstadt	DAG	-	-	1,000	5,000
		TOTAL A, B & C	10,750	38,600	34,050	42,750

ø means the final capacity planned in Dec 1939 or Sep 1944, mostly to be reached years later.

øø means monomethyl amine nitrate plus tetramethyl ammonium nitrate plus methyl nitrate.

If extenders namod under A plus B plus C lacked them dilutes as sodium chloride were used in lots up to 10,000 motos NaCl

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PLANTS FOR PRODUCTION OF HIGHLY CONCENTRATED NITRIC ACID

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POWDER, EXPLOSIVES AND RELATED PRODUCTS · EXHIBIT G

Plants for Production of Highly-Concentrated Nitric Acid (Hokosaure)

Capacity metric tons per month

No	Plants and locations	Firm	Dec 1939 Reached	Dec 1939 Planned#	Dec 1944 Reached	Dec 1944 Planned#
1	Oppau (Ludwigshafen-Rhine)	I. G. Farben	2,500	3,500	3,600	6,700
2	Hochst (Frankfort-Main)	I. G. Farben	8,500	8,500	10,000	12,700
3	Wolfen (Bitterfeld)	I. G. Farben	3,800	7,500	9,750	13,650
4	Leuna (Merseburg)	I. G. Farben	600	3,800	3,300	3,300
5	Pesteritz (Wittenberg-Elbe River)	Bayer, Stickstoffwerke	2,500	4,000	5,250	5,850
6	Sondershausen (Erfurt-Thuringia)	Wifo (Kalichemie)	2,500	2,500	2,500	2,500
7	Doberitz (Berlin)	Wifo (I. G. Farben)	2,500	5,000	5,000	5,000
8	Moscice (Poland)	Oberschlesische Stickstoffwerke	2,000	2,000	-	-
9	Melbeck-Embsen (Luneburg)	Wifo (I. G. Farben)	5,000	5,000	5,000	8,500
10	Langelsheim (Hartz-Mountains)	Wifo (I. G. Farben)	-	5,000	4,800	4,800
11	Konigshutte (Kattowice-Silesia)	Oberschlesische Stickstoffwerke	-	2,500	2,500	2,500
12	Igling (Bavaria)	Wifo (I. G. Farben)	-	5,000	-	-
13	Linz (Austria)	Wifo (Stickstoffwerke Ostmark)	-	3,500	5,000	6,000
14	Heydebreck (Upper Silesia)	Wifo (I. G. Farben)	-	6,500	-	10,000
15	Christianstadt (Frankfort-Oder R)	Dynamit AG	-	-	5,750	9,400
16	Rhina (Basel)	Elektro-Nitrum AG	-	-	50	50
17	Aussig (Prague)	Chem. Werke Aussig	-	-	50	50
18	Holten (Essen)	Ruhrchemia AG	-	-	-	2,500
		TOTAL:	29,900	64,300	62,550	92,500

means the final capacity planned in December 1939 or September 1944, mostly to be reached years later.

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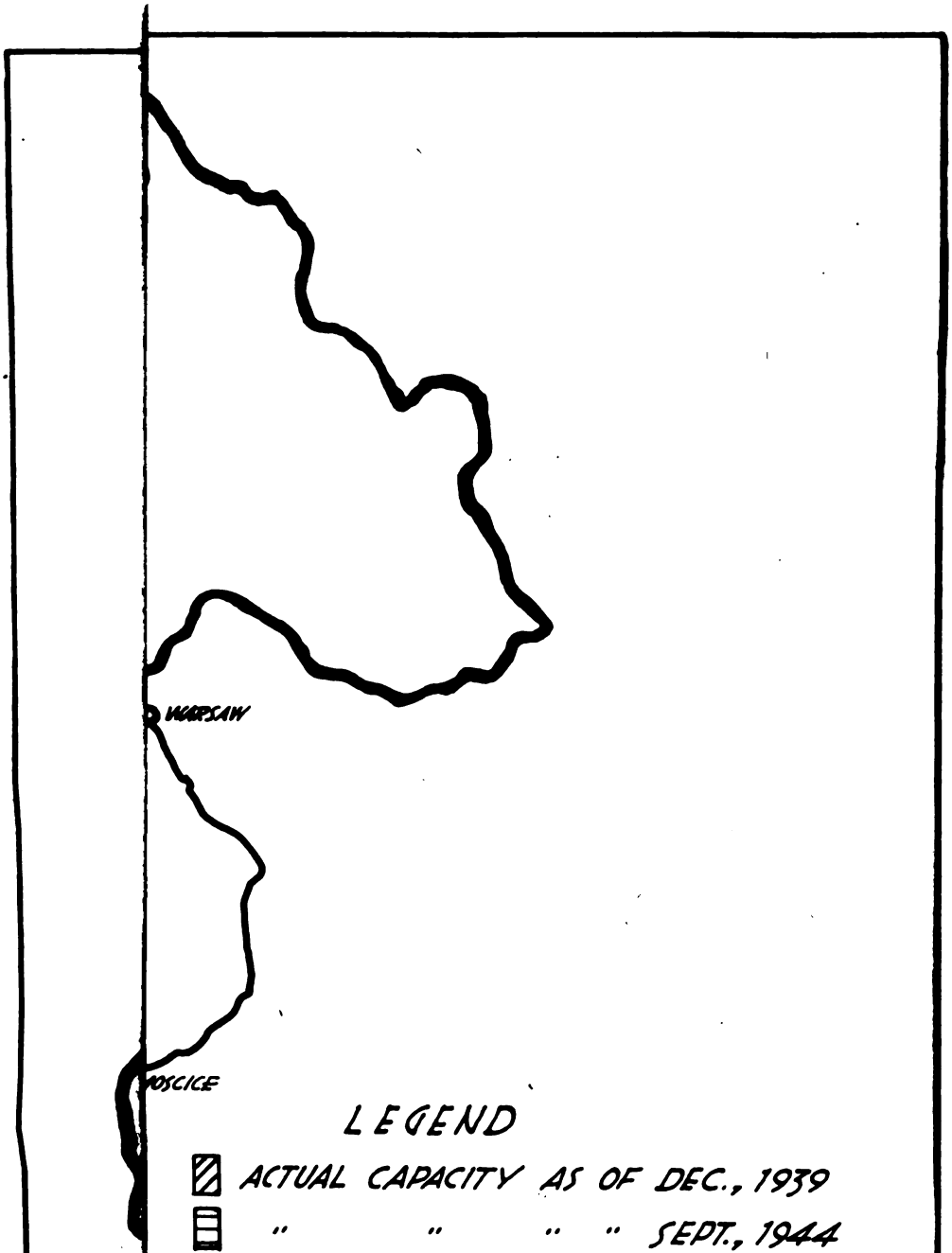

S FOR CONCENTRATED NITRIC ACID

EXHIBIT G

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PLANTS FOR PRODUCTION OF OTHER RAW MATERIALS FOR POWDERS AND EXPLOSIVES

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POWDER, EXPLOSIVES AND RELATED PRODUCTS — EXHIBIT H

Plants for Production of Raw Materials for Powders and Explosives

Capacity metric tons per month

No.	Plant and Location	Firm	Dec 1939 Reached	Dec 1939 Planned	Sep 1944 Reached	Sep 1944 Planned
1.	Toluene:					
	from coal at Ruhr, Saar and Silesia	.....	3,200	4,300	8,200	8,500
	Waldenburg (Silesia)	I. G. Farben	-	3,000	4,000	5,000
	Holten (Ruhr)	Ruhrchemie AG	-	1,300	-	1,200
	Ludwigshafen (Rhine)	I. G. Farben	-	-	-	800
	Poelitz (Stettin)	Hydrierw. Poelitz	-	1,000	-	-
		TOTALS:	3,200	9,600	12,200	15,500
2.	Diglycol:					
	Wolfen (near Bitterfeld)	I. G. Farben	500	500	500	750
	Schkopau (near Halle)	Bunaw Schkopau	-	600	700	900
	Gendorf (Munich)	Anorgana GmbH	-	-	1,100	1,400
	Ludwigshafen (Rhine)	I. G. Farben	200	200	450	950
	Huls (near Recklinghausen-Ruhr)	Chem. W. Huels	-	1,250	1,100	1,100
	Auschwitz (Upper Silesia)	I. G. Farben	-	-	-	1,350
	Trostberg/Hart (near Salzburg)	Suedd Kalkstick-stoffwerke	-	600	-	-
		TOTALS:	700	3,150	3,850	6,450
3.	Hexamethylentetramine:					
	Christianstadt (Frankfort-Oder)	Dynamit AG	-	-	2,100	3,600
	Doeberitz (near Berlin)	"	-	-	600	600
	Elberfeld (Wuppertal)	I. G. Farben	-	-	750	750
	Fuerstenberg (Frankfort-Oder)	Degussa	-	-	750	1,500
	Wildau (near Berlin)	"	-	-	400	400
	Schwarza (Thuringia)	Thuer. Zellwolle AG	-	-	45	45
		TOTALS:	-	-	4,645	6,895

● means the final capacity planned in Dec 1939 or Sep 1944, mostly to be reached years later.

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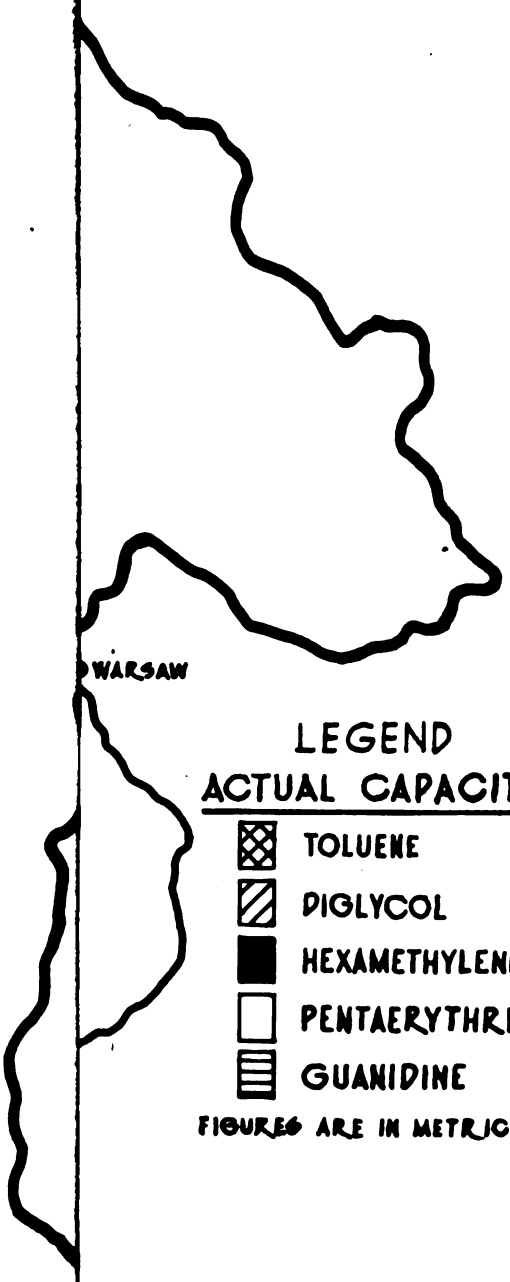

R OTHER RAW MATERIALS
WDER AND EXPLOSIVES

EXHIBIT H

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POWDER, EXPLOSIVES AND RELATED PRODUCTS EXHIBIT H

Plants for production of primary materials for powders and explosives

Capacity metric tons per month

No	Plant and location	Firm	Dec 1939 Reached	Dec 1939 Planned Ø	Sep 1944 Reached	Sep 1944 Planned Ø
4.	Pentaerythritol:					
	Ludwigshafen (Rhine)	I. G. Farben)		-	300	360
	Niederlehne (near Berlin)	Degussa)	Start of plans	-	270	320
	Schrobenhausen (near Augsburg)	Degussa)	locations and	-	200	200
	Welden (near Augsburg)	Degussa)	capacities not	-	185	200
	Wildau (near Berlin)	Degussa)	yet fixed	-	70	70
	Lippoldsberg (Detmold-Weser)	Degussa)		-	-	300
			TOTALS:		1,025	1,450
5.	Guanidine:					
	Pfesteritz (Wittenberg-Elbe River)	Bayer. Stickstoffwereke AG	50	1,500	1,000	2,100
	Leverkusen (near Cologne-Rhine)	I. G. Farben			450	450
		TOTALS:	50	1,500	1,450	2,550

Ø means the final capacity planned in Dec 1939 or Sep 1944, mostly to be reached years later.

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ANNUAL PRODUCTION OF KRUMMEL PLANT

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POWDER, EXPLOSIVES AND RELATED PRODUCTS EXHIBIT I

Annual Production of Krummel Plant ø
Figures in metric tons per year

Production	1939	1940	1941	1942	1943	1944	1945 to 7 Apr '45	Yearly capacity tons
Nitroglycerine	1,772	759	715	233	472	480	92	6,000
Nitro-Glykol	55	387	357	369	446	559	129	6,000
Diglykol-Dinitrat	2,870	4,310	5,332	6,384	9,414	8,803	714	18,000
Methriol-Trinitrat (Pilot Plant)	-	-	5	14	16	16	-	
Trigiykol-Dinitrat (" "	-	-	48	139	196	97	-	
Nitropenta	483	1,311	1,676	1,722	1,686	1,962	426	2,160
Nitrocellulose	3,760	5,169	7,688	10,816	13,102	12,773	1,829	15,600
T N T	9,834	16,207	25,193	25,739	25,192	31,443	4,792	33,600
Hexogen (W-Salz)	-	566	783	903	924	299	-	1,200
Mining Explosives	3,091	3,084	2,725	2,900	5,185	5,809	896	-
Raw Cordite Paste	10,803	14,341	18,511	21,984	29,951	28,476	2,845	-
Poured Filling, Old Factory	6,326	18,489	17,304	9,144	10,392	12,955	700	-
Difa Factory	-	-	-	-	-	853	113	-
Pressed T N T Filling	-	-	-	-	2,359	2,299	241	-
Pressed Filling Nithopenta	145	263	330	294	403	401	91	-
Plastics	-	-	195	1,256	1,809	1,851	308	-
Sulphuric Acid Tons So	9,907	9,846	9,980	9,874	9,619	8,898	1,920	-

ø Source: Economic Advisory Branch British Ministry of Economic Warfare.

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J - SPEER MINISTRY DATA FOR ANNUAL PRODUCTION, CONSUMPTION AND EXPORT OF POWDER AND EXPLOSIVES, 1938 - 1941

J1 AND 2 - TOTAL POWDER AND EXPLOSIVES 1942 - 43

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EXHIBIT J

SPEER MINISTRY DATA FOR ANNUAL PRODUCTION, CONSUMPTION AND EXPORT OF POWDER AND EXPLOSIVES, 1938-1941

Berlin, 22 October 1941

Explosives (Data in tons)	1938	1939	1940	1941
Production				
1) for military requirements	25,000	68,100	174,000	268,000
2) for civilian purposes	39,500	45,800	46,500	50,000
Total	64,500	113,900	220,500	318,700
Military consumption		18,244	70,401	89,673
Civilian consumption	39,500	45,800	46,500	50,700
German consumption	39,500	64,044	116,901	140,373
Export		1,800	7,300	4,800
Total Consumption	39,500	65,844	124,201	145,173
Powder (figures in tons)				
Production	32,000	49,000	75,600	135,600
Total	32,000	49,000	75,600	135,600
Military consumption		5,300	25,000	30,000
German consumption		5,300	25,000	30,000
Export		650	2,650	2,300
Total consumption		5,950	27,650	32,300

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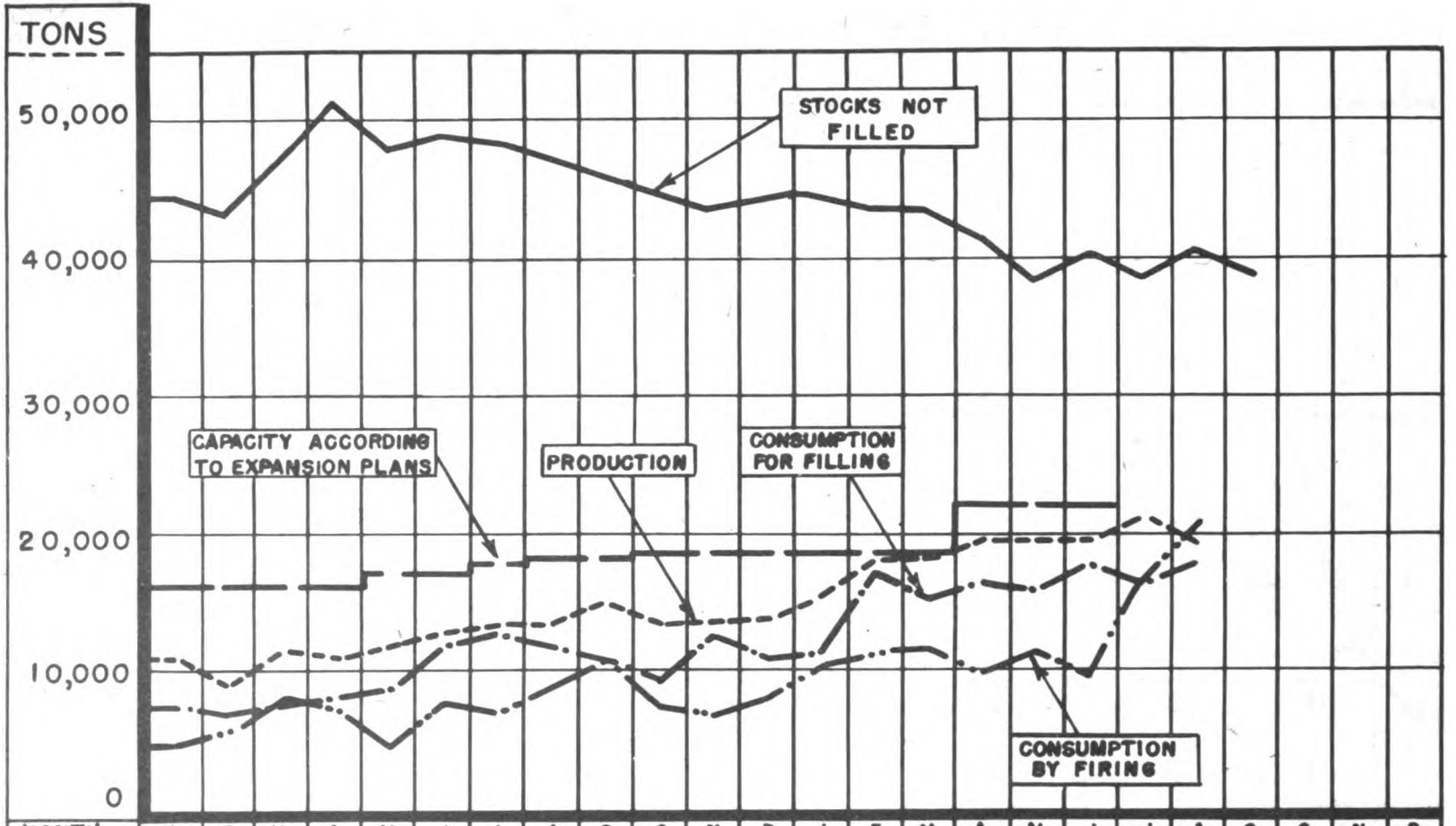
TOTAL POWDER



MONTH	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
YEAR	1942												1943											
STOCK IN AMO.	127	128	129	130	133	142	146	158	155	158	150	166	167	166	170	155	174	180	188	192	192			
STOCK IN TRANSIT								62.6	66.6	60.5	56.0	56.7	57.1	51.8	50.0	42.5	51.8	44.3	55.3	59.0	56.1			

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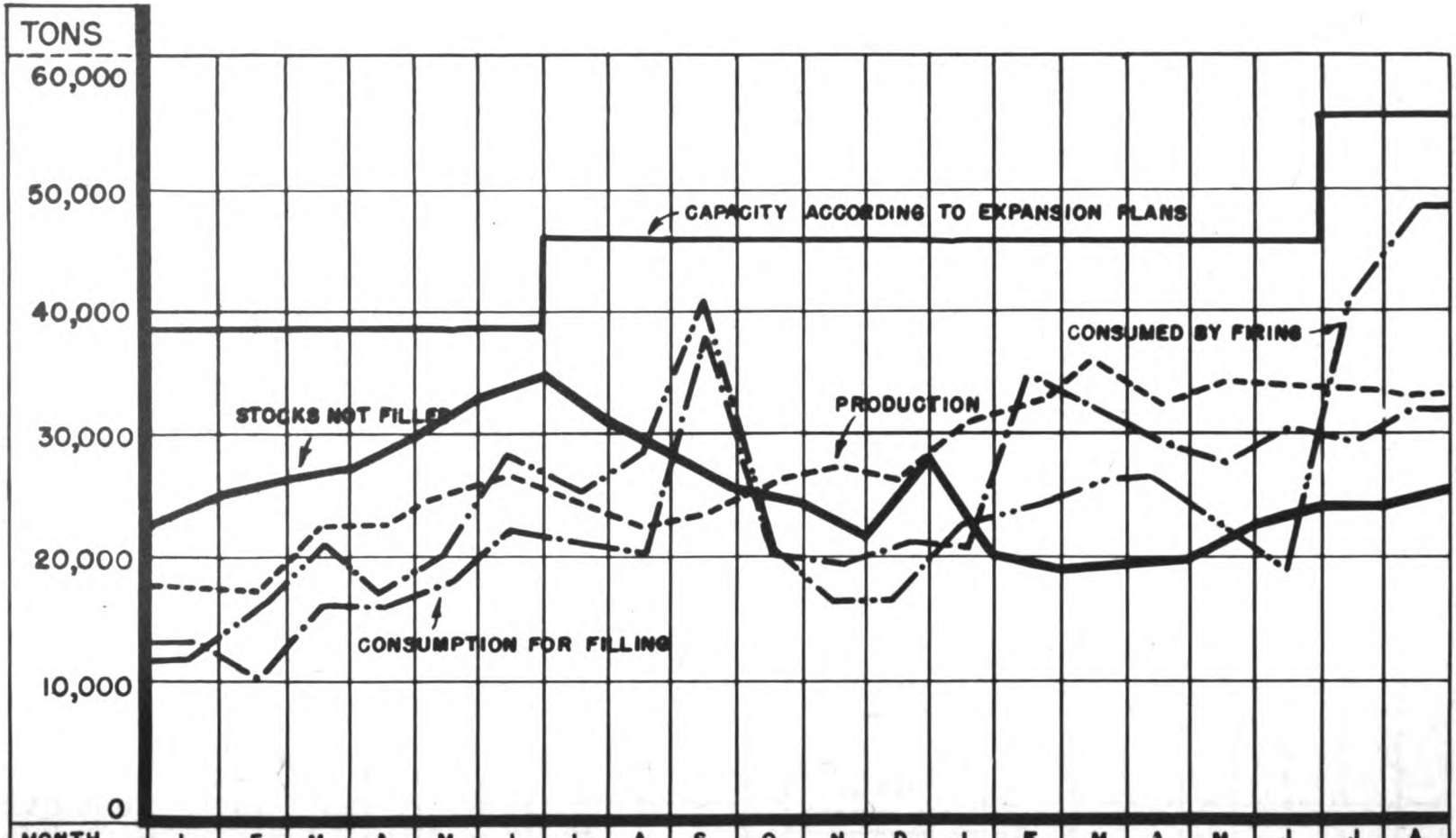
EXHIBIT J-1

TOTAL EXPLOSIVES



MONTH	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
YEAR	1942												1943							
STOCKS IN FILLED AMO.	280	282	280	279	273	277	277	277	270	282	284	288	291	292	304	303	312	319	334	331
STOCKS IN TRANSIT								83.3	77.9	72.3	53.6	64.8	58.0	67.8	63.8	54.6	66.2	45.1	74.9	69.3

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EXHIBIT J-1

K1 AND 2 - POWDER AND EXPLOSIVES CONSUMPTION BY WEHRMACHT, AND PRODUCTION

K3 POWDER EXPLOSIVES CONSUMPTION BY WEHRMACHT PRODUCTION

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EXPLOSIVES

PRODUCTION AND CONSUMPTION BY THE ARMED FORCES
GREATER GERMANY

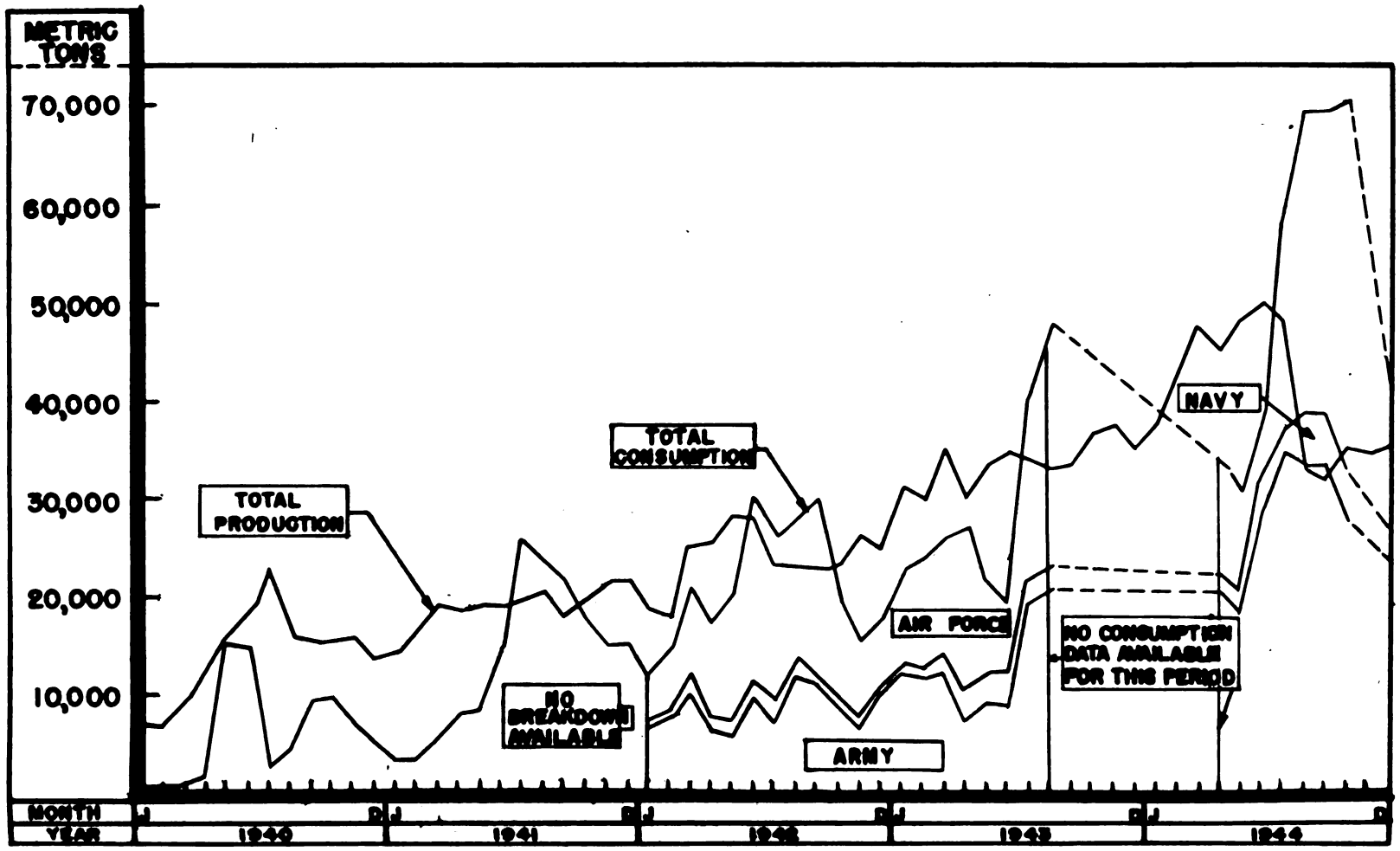

EXHIBIT K-1

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POWDER

PRODUCTION AND CONSUMPTION BY THE ARMED FORCES

GREATER GERMANY

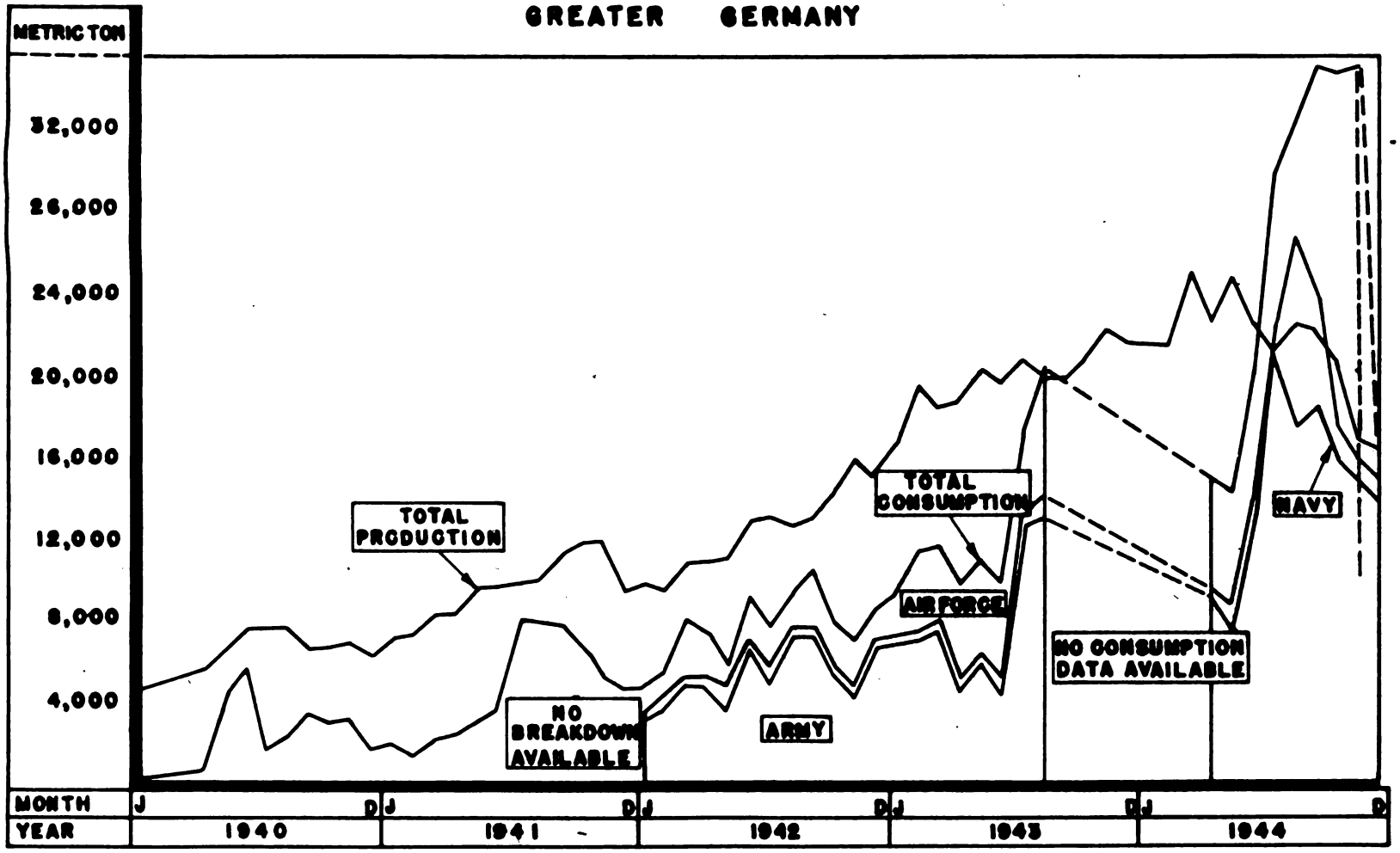

EXHIBIT K-3

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EXHIBIT K

MONTHLY PRODUCTION OF POWDERS AND EXPLOSIVES (INCLUDING MATERIALS) AND CONSUMPTION BY ARMED ARMY FORCES

IN METRIC TONS

Year And Month	Powders						Explosives					
	Production	Consumption				Stocks	Production	Consumption				Stocks
		Army	Navy	Air	Total			Army	Navy	Air	Total	
1940												
Jan	4,300				100		6,500				500	
Feb	4,800				100		6,000				400	
Mar	5,200				200		9,000				500	
Apr	5,600				500		12,800				1,700	
May	6,400				4,100		16,200				15,200	
Jun	7,500				5,600		18,800				15,000	
Jul	7,600				1,700		22,900				2,500	
Aug	7,500				2,100		16,000				4,400	
Sep	6,400				2,500		15,300				9,200	
Oct	6,500				3,000		15,300				9,500	
Nov	6,300				3,400		15,700				6,900	
Dec	6,100				1,500		13,400				4,500	
Total	74,800				25,600	49,000	168,500				70,400	96,100
1941												
Jan	7,000				1,900		14,300				3,200	
Feb	7,100				1,200		16,500				3,600	
Mar	7,900				2,000		19,200				5,500	
Apr	8,000				2,300		18,800				8,100	
May	9,500				3,000		19,300				8,500	
June	9,500				3,700		19,400				14,200	
July	9,500				7,900		20,153	7,890	1,370	17,100	26,360	
Aug	9,000				7,800		20,949	9,036	362	15,130	24,528	
Sep	11,100				7,700		18,300				22,800	
Oct	11,600				6,400		20,000				17,700	
Nov	11,800				5,000		21,728	6,104	309	8,812	15,225	
Dec	9,300				4,500		21,823	6,664	424	8,349	15,437	
Total	111,400				53,400	58,900	230,453				165,150	65,038
Cumulative 1940-1941						107,900						163,138
1942												
Jan	9,812	2,941	443	1,362	4,746		18,972	6,587	815	4,707	12,109	
Feb	9,417	3,735	379	1,104	5,218		16,197	7,762	798	5,893	14,443	
Mar	10,765	-	-	-	7,900		25,438	-	-	-	20,900	
Apr	10,722	4,600	305	2,692	7,597		25,702	6,713	1,002	9,798	17,513	
May	11,017	3,400	1,095	1,188	5,683		28,685	5,758	2,321	12,462	20,571	
June	12,698	6,478	346	2,803	9,627		28,467	9,790	1,528	19,318	30,636	
July	13,019	4,580	573	2,497	7,650		23,547	7,027	2,022	17,232	26,281	
Aug	12,585	-	-	-	9,900		23,299	-	-	-	28,500	
Sep	12,974	6,900	266	3,090	10,256		23,105	11,251	1,190	17,918	30,359	
Oct	13,985	5,258	271	2,297	7,826		23,917	8,522	1,216	11,971	22,109	
Nov	15,969	4,134	304	2,131	6,569		24,420	6,710	1,056	7,798	15,564	
Dec	15,009	6,265	225	1,727	8,215		25,014	9,919	909	6,637	17,465	
Total	147,870				90,587	57,282	290,783				256,450	34,291
Cumulative 1940-1942						165,182						197,429
1943												
Jan	16,700	6,484	382	2,440	9,306		31,400	12,440	867	9,338	22,665	
Feb	19,500	-	-	-	11,500		30,100				24,200	
Mar	18,300	7,394	462	3,931	11,788		35,900	12,579	1,595	11,978	26,152	
Apr	18,900	4,493	307	4,658	9,457		30,000	7,935	2,364	16,848	27,147	
May	20,300	5,874	197	5,026	11,097		33,900	9,539	2,568	9,412	21,147	
June	19,000	4,588	227	4,652	9,547		35,400	9,304	3,217	6,560	19,281	
July	20,600	12,412	360	4,412	17,184		34,400	19,675	1,921	19,092	40,686	
Aug	19,900	13,223	729	6,326	20,278		33,700	20,965	2,459	25,339	46,763	
Sep	20,000	-	-	-			34,400	-	-	-	-	
Oct	20,500	-	-	-			37,200	-	-	-	-	
Nov	22,100	-	-	-			38,200	-	-	-	-	
Dec	21,600	-	-	-			35,800	-	-	-	-	
Total	238,200						410,400					
Total 6 months					130,157	88,200					330,435	30,400
Calculated Total 12 months					150,000	255,282					380,000	227,624

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EXHIBIT K3
MONTHLY PRODUCTION OF POWDERS AND EXPLOSIVES (INCLUDING EXTENDERS) AND CONSUMPTION BY GERMAN ARMED FORCES IN METRIC TONS

Year And Month	Powders						Explosives					
	Production	Consumption Army	Navy	Air	Total	Stocks	Production	Consumption Army	Navy	Air	Total	Stocks
1944												
Jan	21,700	9,100					38,500					
Feb	21,600	7,400					43,600					
Mar	24,700	13,700					48,600					
Apr	22,500	29,100	400	5,600	15,100		46,000	21,300	1,700	11,800	34,800	
May	24,700	17,400	1,300	5,300	14,000		49,600	19,200	1,900	10,100	31,200	
June	22,500	13,700	1,200	5,000	19,900		51,000	28,900	3,100	6,800	38,800	
July	21,100	21,200	1,100	8,000	30,300		49,300	35,800	1,900	21,700	59,400	
Aug	22,400	17,700	8,900	8,900	35,500		33,600	34,300	5,200	31,300	70,800	
Sept	22,100	18,500	5,300	11,500	35,300		32,300	34,300	5,200	31,500	71,000	
Oct	20,600	15,991	1,778	17,858	35,627		35,900	29,117	4,646	38,312	72,075	
Nov	17,300						35,200					
Dec	16,600	13,833	819	5,002	19,654		31,300	24,726	2,333	11,064	38,123	
Total	257,800						494,900					Including insert extenders
Total 8 months					205,181						416,198	
Calculated total 12 months					307,100	44,000					624,000	129,602
Cumulative 1940-1944						209,382						98,222
		Summary						Summary				Cumulative Stocks
1940	74,800				25,800	49,000	168,500				70,400	98,100
1941	112,300				53,400	58,900	230,183				165,150	163,133
1942	147,870				90,588	57,282	290,783				256,492	197,424
1943	238,200				150,000	88,200	410,400				380,000	227,824
1944	263,100				307,100	44,000	494,900				624,000	98,222
		Balance January 1, 1945				297,982						

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TNT ALLOCATIONS

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TNT ALLOCATIONS

MONTHLY AVERAGE PER QUARTER YEAR

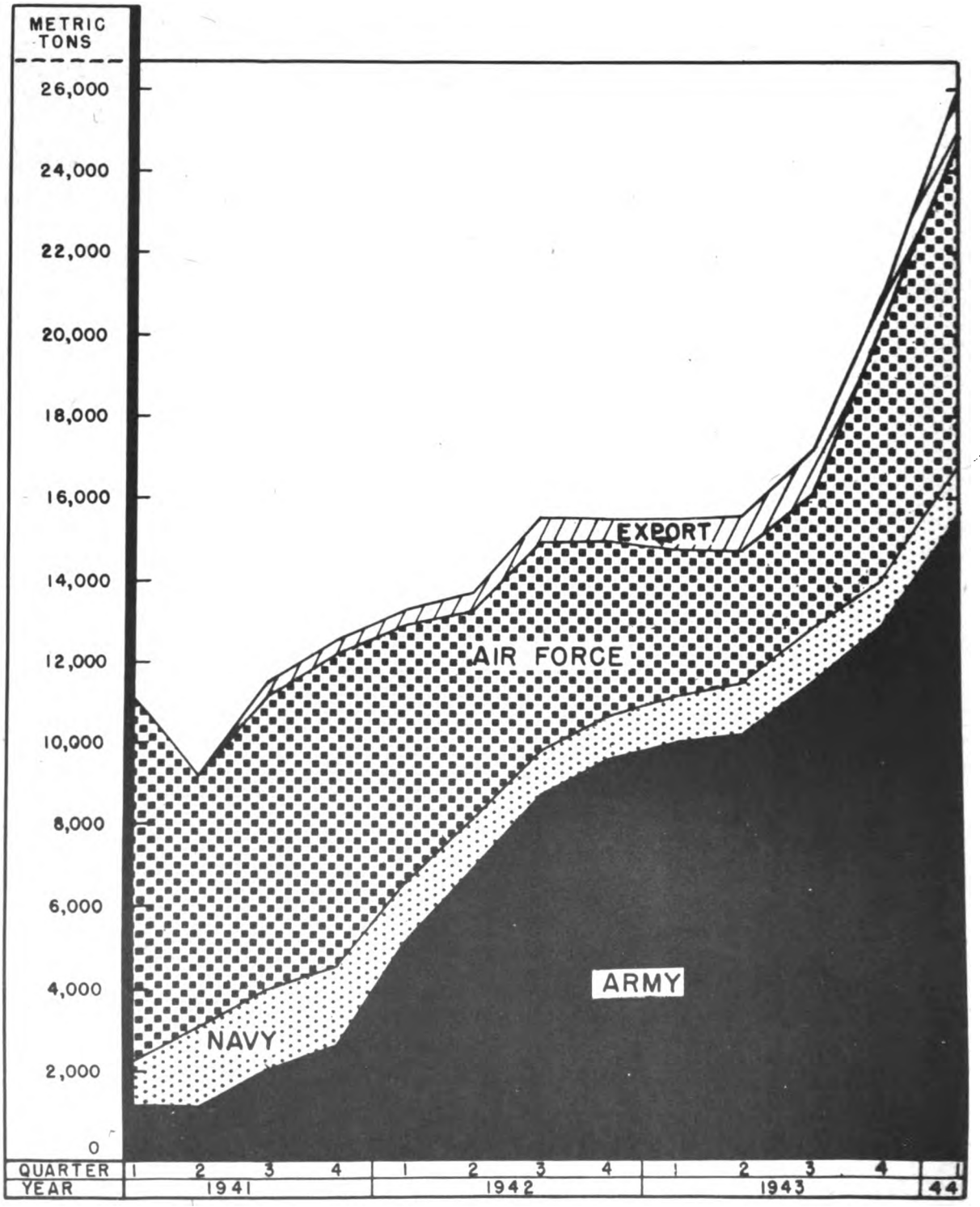

EXHIBIT L

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GERMAN CAPACITY OF FILLING LINES
(KAPAZITATEN DER FULLSTELLEN)

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THE NUMBERS GIVEN (METRIC TONS PER MONTH) FOR HAND GRENADES, THE HANDLE GRENADE (POTATO MASHER), FOR MORTAR SHELLS

NO.	WORKS	COMPANY	KIND OF LOADING PLANT	SMALL MUNITIONS TONS/MO	REMARKS
A	B	C	D	Z	
1	AMBERGEN	FZ-JN	GR		SPECIAL PLANT FOR MORTAR SHELLS
2	ALLENDORF	VERWERT	U		2 MEISSNER SECTIONS EACH OF 96 COMPARTMENTS. FOR SECTION I 5000 TONS/MO AMATOL. T PLANT NOT IN OPERATION
3	ALTENBERG	HASAG	KL		DISPERSAL PLANT FOR ANTI-TANK ROCKET. SPECIAL PLANT FOR RIFLE GRENADE
4	ALTENGRABOW	FZ-JN	GR		SPECIAL PLANT FOR MORTAR SHELLS
5	BERNAU	BERGMANN	KL		SPECIAL PLANT FOR RIFLE GRENADES
6	BLUMAU	SR W.B.	HG		
7	BOHUSLAWITZ	DETONA	U		
8	BROMBERG	VERWERT	B		BOMBS UP TO 6000 TONS/MO FORECAST BY END-1945
9					PLANNED FOR MORTAR SHELLS
10	CHRISTIANSTADT	VERWERT	B KL		SMALL MUNITIONS. 3.7 FLAK SHELLS (1000000 PIECES) TOTAL 6000 TONS/MO BOMBS IN CONSTRUCTION
11	CLAUSTHAL	"	U		FOR TELLER MINES OR WOOD MINES
12	DAHLEM	SP. V.G.	KL		EXPERIMENTAL PLANT OF SP. VG.
13	DOMITZ	VERWERT	U		
14	DRAGAHN	WACO	KL		NOW, ANTI-PERSONNEL MINES (SD I) INSTEAD OF MORTAR SHELLS
15	DUBNICA	SKODA	GR		1 MEISSNER 120 COMPARTMENTS. SECTION I. THE CAPACITY IS FOR MINES 10 S
16	ELSNIG	WASAG	U SP		PLANNED CONSTRUCTION BEGINNING 1945
17	ELSNIGK	FZ-JN	GR		
18	GERETSRIED	DSC	GR KL		CURRENTLY 12 CM. MORTAR SHELLS
19	GRASHWITZ	SP U.ZW GR	HG		SMALL MUNITIONS, ICE MINES
20	GUSEN	VERWERT	U SP	400	1 MEISSNER 96 COMPARTMENTS 10 SCREW PRESSES (9 SPINDLE)
21	GUSTROW	FZ-JN	GR		
22	HAMBUHREN	OKL	GR		2 MEISSNER 96 COMPARTMENTS
23					
24	HERRENWALD	WASAG	B KL		SPECIAL PLANT FOR MINES. ALSO SUITABLE FOR BOMBS OF ANY SIZE
25	HERTINE	VERWERT	B		
26	HERTZBERG	"	B		RECONSTRUCTION OF DAMAGED PLANT NO.2 AT THE BEGINNING OF 1945
27	HESSISCH-LICHTENAU	"	U		NOW 12 CM MORTAR SHELLS INSTEAD OF SHELLS
28	HOHENBRUNN	FZ-JN			SPECIAL PLANT FOR HELLING PROCESS. OPERATIONS STARTING END OF 1944. CAPACITY 840 TONS/MO. 800 LIGHT FIELD HOWITZER SHELLS
29	JUTERBOG	FZ-JN	GR		2 MEISSNER 72 COMPARTMENTS. 1 SECTION CONVERTED TO HELLING PROCESS
30					
31	KAUFBEUREN	SP VG	KL		SMALL MUNITIONS: 2 CARTRIDGES, ANTI-PERSONNEL MINES SD 4 NL
32	KLAUEN	FZ-JN	GR		
33	KRIEWALD	SPOS	KL HG		NOW ANTI-PERSONNEL MINES SD I INSTEAD OF MORTAR SHELLS
34	KRUMMEL	DAG	U SP	500	INSTEAD OF 1500 TONS/MO BOMBS. 1000 T. MINES OR 840 SHELLS SMALL MUNITIONS OR MORTAR SHELLS
35	KRUPPAMUHLE	LIGNOSE	AM		PLANT FOR PREPARATION OF AMMONAL. NOT IN OPERATION
36	KUCHELNA	VERWERT	GR		CURRENTLY ANTI-PERSONNEL MINES SD I
37	LAMBACH	OKL	GR		1 MEISSNER 96 COMPARTMENTS
38	LUBBERSTADT	"	GR		SPECIAL PLANT FOR MINES 1 MEISSNER WITH 72 COMPARTMENTS (MAKESHIFT)
39	LUDWIGSDORF	VERWERT	KL		BEGINNING IN OCT. 1944 WITH 3.7 CM FLAK SHELLS
40	MALMITZ	"	KL		
41	MUNSTER	FZ-JN	GR		
42	NEUMARKT	PYROFAG	GR		
43	NEURISSHOFF	SOHLER			SUBSTITUTE PLANT FOR ENZESFELD IN CONSTRUCTION
44	NEURUPPIN	FZ-JN	GR		
45	NIENBERG	OKL	GR		2 MEISSNER 96 COMPARTMENTS
46	NIVELLES	DWM	KL		
47	NURSCHAN	SKODA	GR		6 SCREW PRESSES PLANNED. STARTING DATE STILL UNDETERMINED
48	OBER-LAZISK	SPR OS	HG		BOMB CAPACITY. PREPARATION OF AMMONAL. NOT IN OPERATION.
49	PETERSDORF	VERWERT	GR		
50	POLICKA	SKODA	GR		9 SCREW PRESSES PLANNED. STARTING DATE STILL UNDETERMINED
51	PREMNITZ	VERWERT	SP		16 SCREW PRESSES PLANNED. STARTING DATE STILL NOT CLARIFIED
52	REINSDORF	WASAG	U		
53	SALZUNGEN	WUHLE	GR KL		ANTI-TANK ROCKETS. THIS PLANT WILL BE INCREASED TO ABOUT
54	SCHLIEBEN	HASAG	KL		2000 TONS/MO STARTING END OF 1944
55	SCHONEBECK	LIGNOSE	HG		
56	SEMTIN	EXPLOSIA	AM		PREPARATION OF AMMONAL. NOT IN OPERATION
57	SPECK	OKL	GR		1 MEISSNER 96 COMPARTMENTS
58	SYTHEN	WASAG	GR HG		CAPACITY IN SECTION. PREPARATION OF AMMONAL. NOT IN OPERATION
59	THERESIENFELD	WUHLE	GR KL		10 SCREW PRESSES
60	TORGAU	FZ JN	GR		ALSO MORTAR SHELLS IN PLACE OF SHELLS
61	UCKERMUNDE	VERWERT	SP		1 DOUBLE MEISSNER WITH 90 COMPARTMENTS. PLANT SPECIAL FOR 10 CM SHELLS (300000)
62	UNTERLUSS	RHEINMETAL	GR		12 SCREW PRESSES. STARTING NOT YET CLARIFIED
63	WOLFRATSHAUSEN	VERWERT			1 MEISSNER FOR 72 COMPARTMENTS. 2 SCREW PRESSES PLANNED
64					1 MEISSNER 20 COMPARTMENTS WITH 2 HEADS FOR 21 CM SHELLS PLANNED
65	MOSCHWIG	DSC	GR		20 SECTION K ATTACHED 360 TONS/MO FOR 21 CM SHELLS (24000 PCS) 2 MEISSNER OF 96 COMPARTMENTS. 1 MEISSNER 120. 2 HEAD COMPARTMENTS

EXHIBIT M

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PRODUCTION SITUATION 1944 - UNUSED CAPACITY

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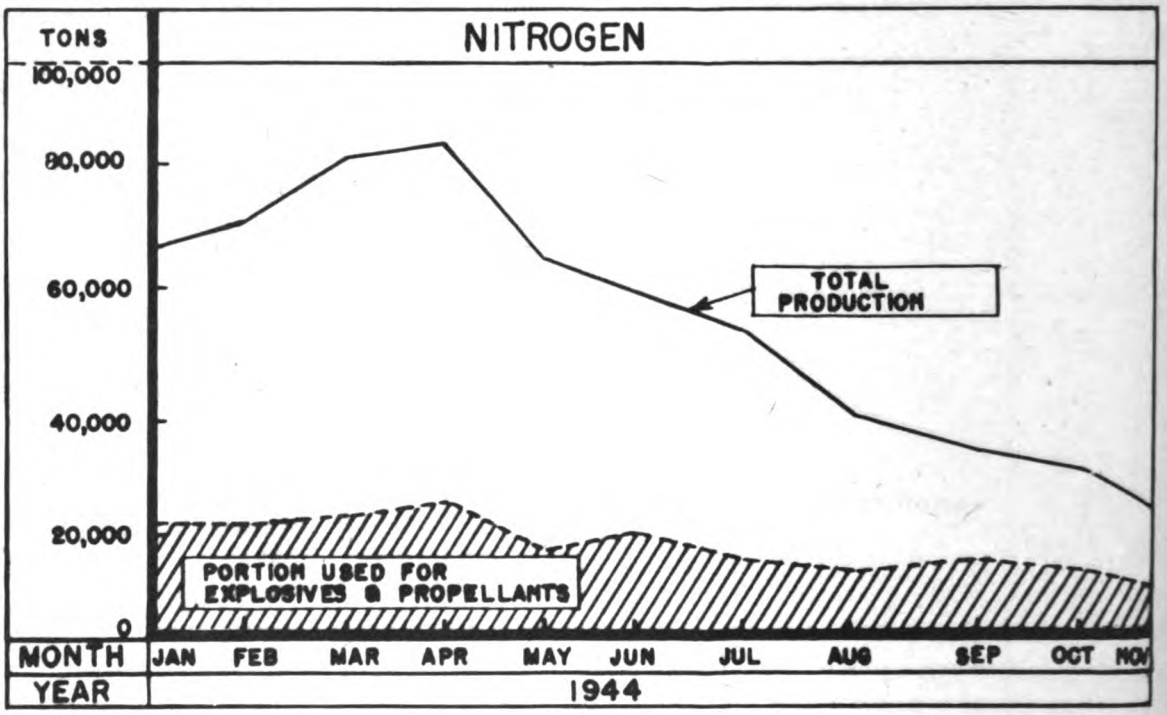
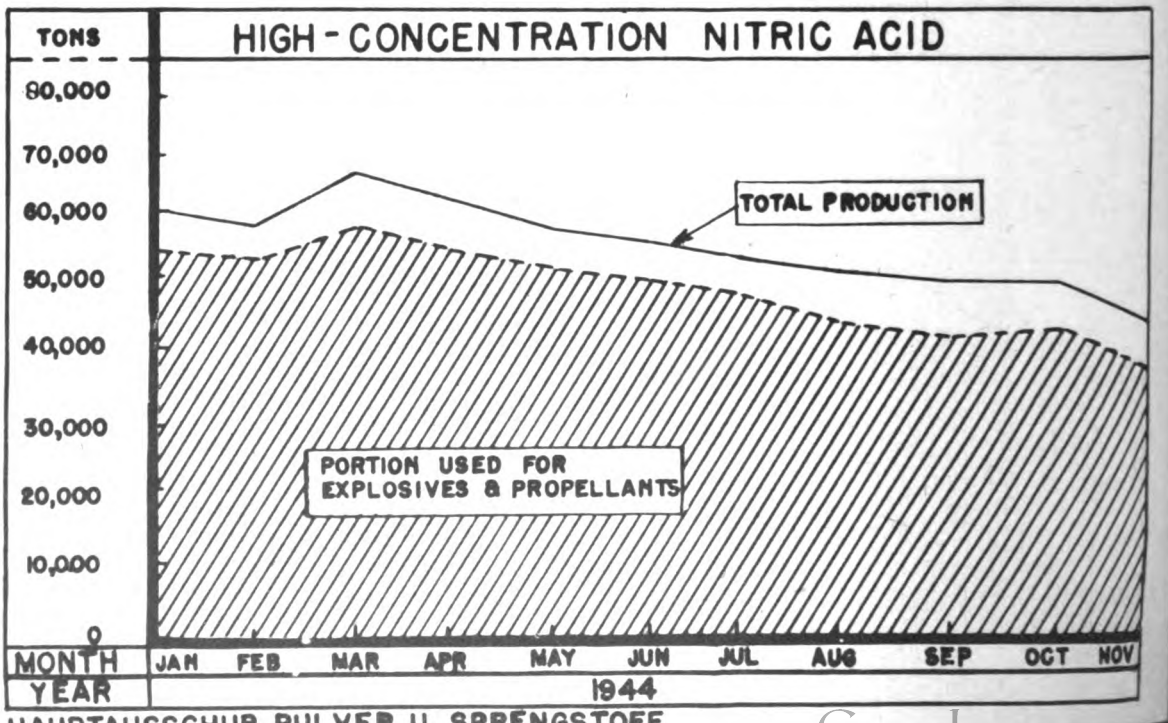
NITROGEN PRODUCTION





HAUPTAUSSCHUB PULVER U. SPRENGSTOFF

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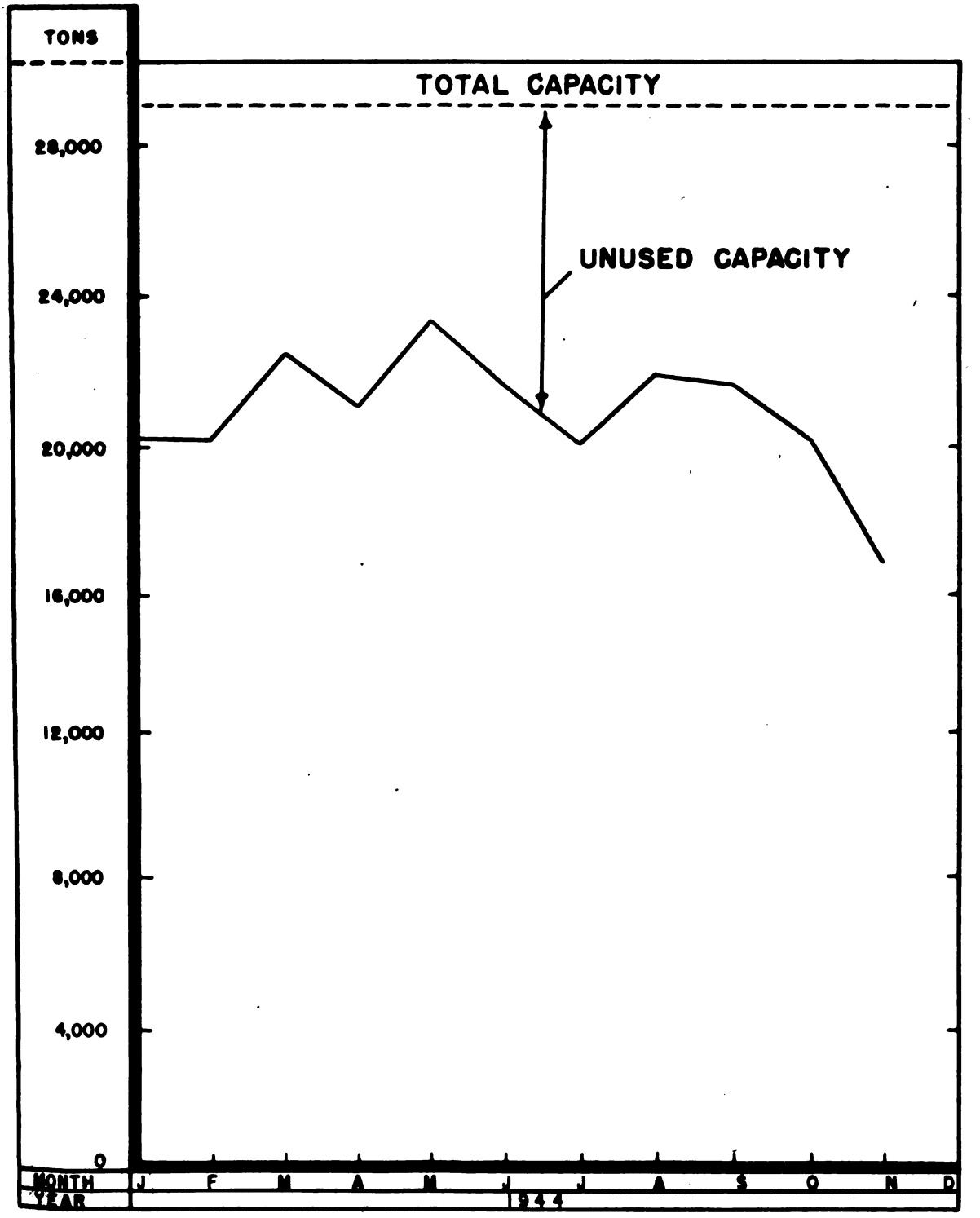
EXH

POWDER PRODUCTION-1944

(DOMESTIC ONLY)



* DATA NOT AVAILABLE FOR DECEMBER 1944

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EXHIBIT N-2

EXPLOSIVES

DOMESTIC AND FOREIGN

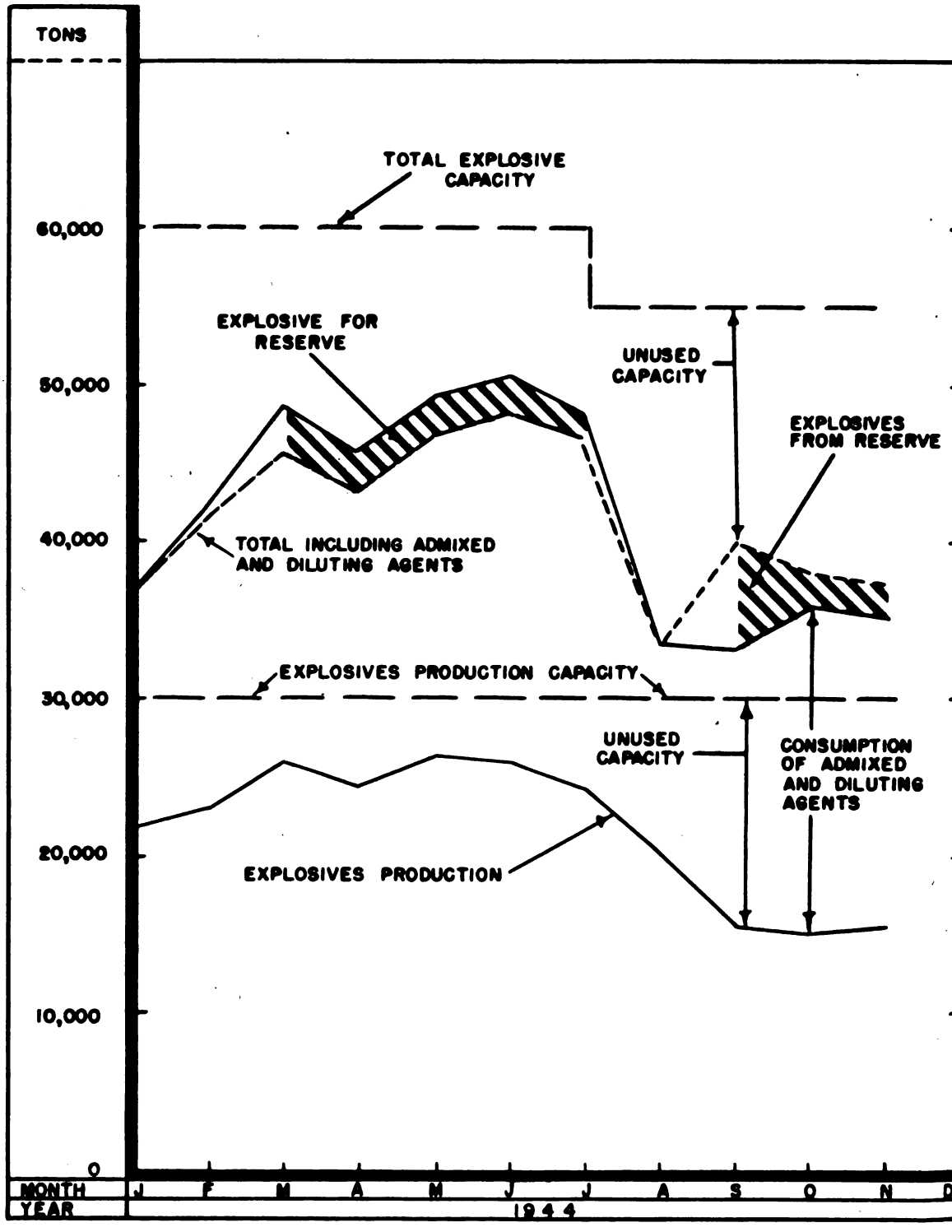

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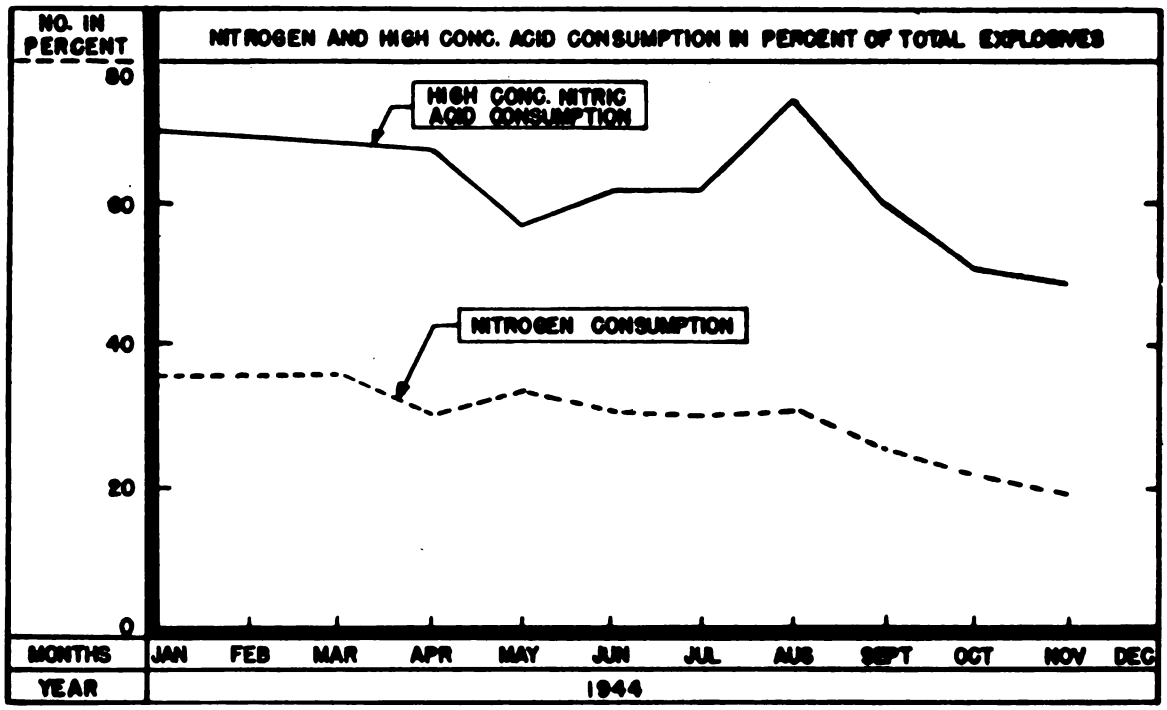
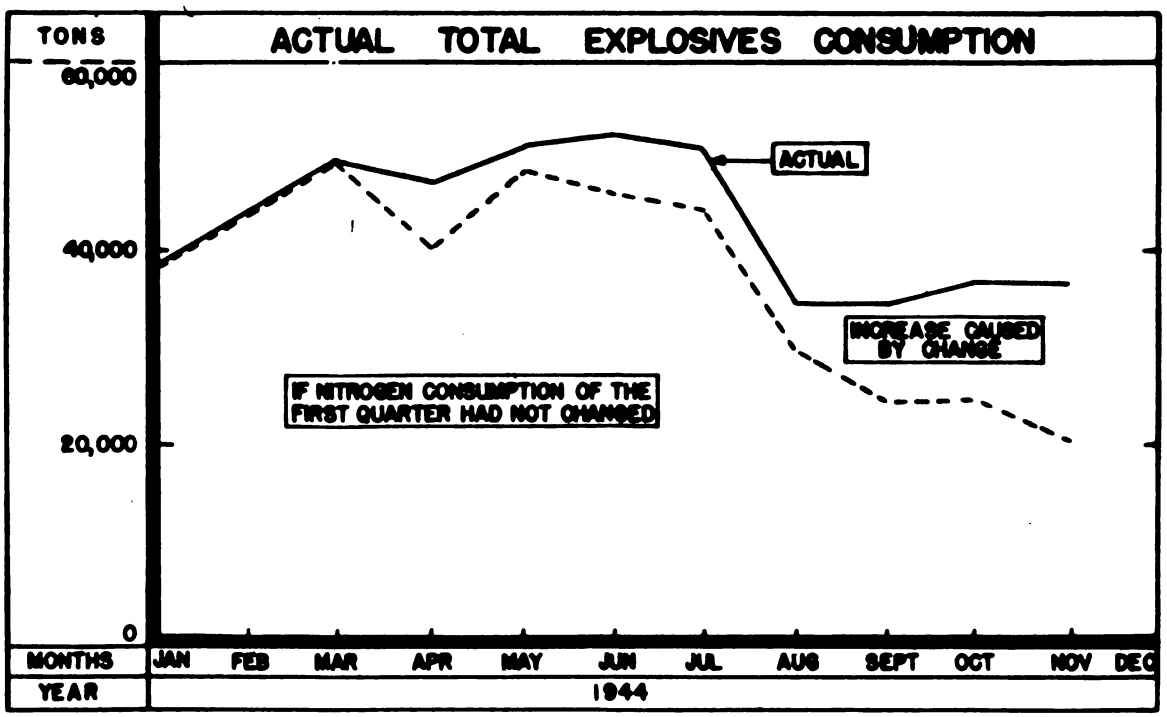
EXHIBIT N-3

NITROGEN AND HIGH CONC. ACID CONSUMPTION





HAUPTAUSCHUE PULVER U. SPRENGSTOFF

EXHIBIT N-4

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NITROGEN SAVING EXPLOSIVES MIXTURES

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Anlage zu Nr. 1716/44 g. Kdos.-Wa Prüf I

Wa Prüf

O.U., den August 1944

Geheime Kommandosache

Stickstoffsparmischungen

Infolge des Ausfalls von Primär-Stickstoffanlagen und des damit verbundenen Absinkens der Ammonsalpeter-Produktion mußten von Wa Prüf Stickstoff-Sparmischungen entwickelt werden. An Ausweichmöglichkeiten waren Natronsalpeter mit einem Stickstoffgehalt von 16,5 % (Ammonsalpeter mit Stickstoffgehalt von 35 %) und völlig stickstoffreier Füllstoff gegeben. Auf Grund der Führerentscheidung vom 21.8.44 konnten nunmehr Mischungen entwickelt und freigegeben werden, die bisher wegen ihres Leistungsabfalls nicht zur Einführung vorgeschlagen werden durften. Beiliegende Tabelle gibt einen Überblick über die entwickelten und neueingeführten Stickstoffsparmischungen.

Die Tabelle zeigt, daß bei dem Füllpulvergemisch Pp 30/70 der Stickstoffgehalt mit 0,608 kg N bei weitem am höchsten liegt. Die Natronsalpetermischungen bringen im Vergleich zu den Füllpulvergemischen nur eine geringe Verminderung des Stickstoffgehaltes. Auf Grund des Führerentscheids wurden Tri/Steinsalzmischungen eingeführt, die eine wesentliche Entlastung des Stickstoffbedarfs bringen.

Die Ammonite sind bei dem derzeitigen Mischungsverhältnis noch erhebliche Stickstoff-Fresser. Die Splitterdichten liegen gleichfalls noch hoch. Es werden von Wa Prüf neue Ammonite entwickelt, die weniger Stickstoff enthalten , und deren Sprengwirkung den neueren Forderungen angeglichen wird.

In beiliegender Sprengstoffübersicht sind die einzelnen Gemische nach ihrer Zusammensetzung, ihrem Stickstoffgehalt und ihrer Splitterdichte aufgestellt.

20 Ausfertigungen
5. Ausfertigung

EXHIBIT O-1

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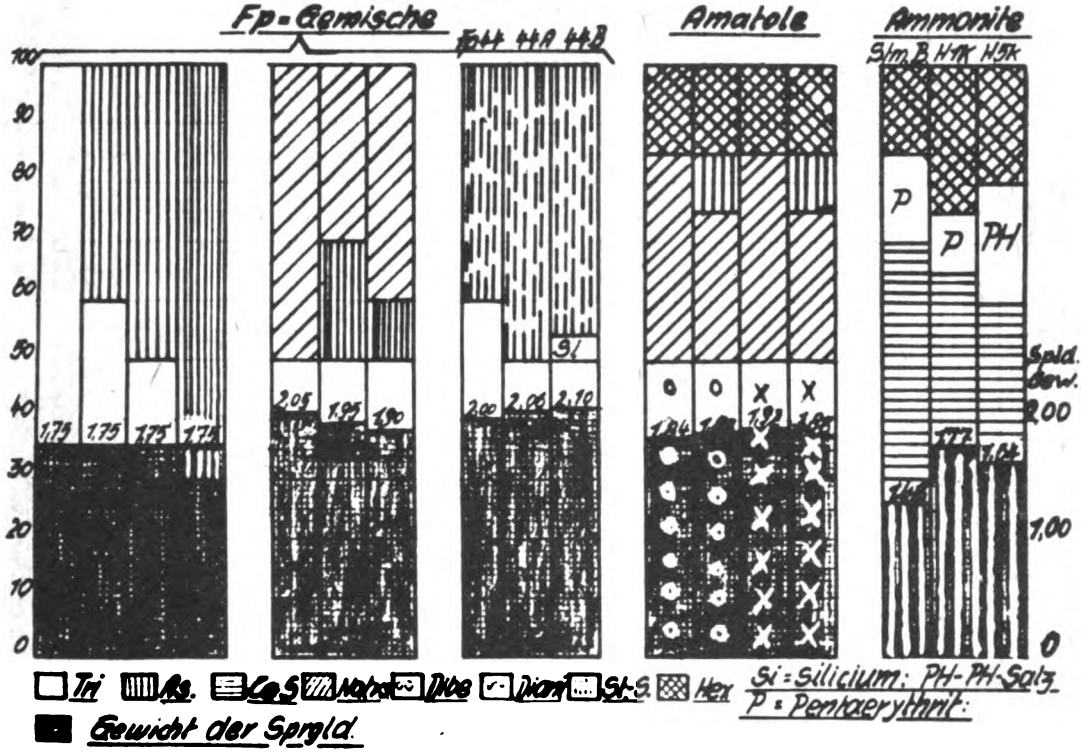
20 Ausfertigungen

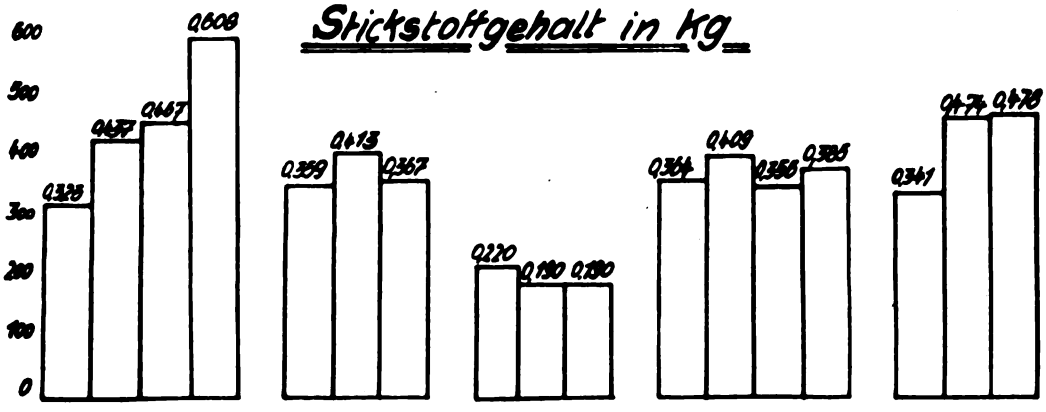
Geheime Kommandosache

5. Ausfertigung

Sprengstoff-Übersicht



Stickstoffgehalt in kg



Splitterdichte 1 in m

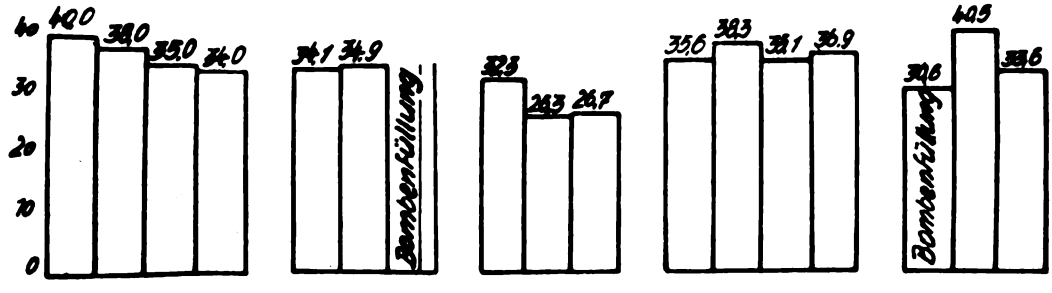


EXHIBIT O-2

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Geheime Kommandosache **Stickstoff-Sparmischungen** 5. Ausfertig.

Anlage zu Nr. 1711/44 g.Kdos.

Anl. zu

noch. Rs.

Sprengstoff-Mischung		Spez. Gew. kg	Stickstoffgeh. kg	Spez. Pot. m	Verwendung in	Kennzahl
100 %	Tri	1,75 kg	0,223 kg	40,0 m	Gesch. Min. Bomb.	14
60/40	Tri/AS	1,75 "	0,237 "	39,0 "	" " "	13
50/50	Tri/AS	1,75 "	0,267 "	35,0 "	" " "	13 A
30/70	Tri/AS	1,75 "	0,305 "	34,0 "	Geschosse	9
50/50	Tri/Nor-S	2,05 "	0,289 "	34,1 "	"	41
50/20/30	Tri, AS, Nor-S	1,95 "	0,[illegible]	34,9 "	"	13 E
50/10/40	Tri, AS, Nor-S	1,90 "	0,367 "	———	Bomben	13 F
60/40	Tri/St-S	2,00 "	0,220 "	32,3 "	Geschosse	23
50/50	Tri/St-S	2,06 "	0,190 "	26,3 "	"	23 A
50/4/46	Tri/Si/St-S	2,10 "	0,190 "	26,7 "	"	23 B
50/35/15	Dide/Nor-S, hex	1,94 "	0,364 "	35,6 "	Gesch. Min. Bomb.	52 C
50/10/25/15	Dide/AS/Nor-S, hex	1,99 "	0,409 "	39,2 "	" " "	52 C
50/35/15	Diani/Nor-S, hex	1,92 "	0,356 "	35,1 "	Geschosse + Min.	17 C
50/10/25/15	Diani/AS/Nor-S/hex	1,99 "	0,395 "	36,9 "	" "	17 C
30/40/15/15	AS/Ca-S/Penta/hex	1,79 "	0,37[illegible] "	30,6 "	Bomben + Minen	Verz. d. Verpulv. mit Zusatz B
35/30/10/25	AS/Ca-S/Penta/hex	1,77 "	0,474 "	40,5 "	Geschosse + Min.	58 K
30/30/20/20	AS/Ca-S/PH/hex	1,64 "	0,479 "	33,6 "	" "	59 K

Erläuterungen:
AS = Ammonsalpeter
NaS = Natronsalpeter
Ca-S = Kalksalpeter
Dide = Dinitrodiglykol
Si = Si-Stoff
Diani = Dinitroanisol
St = Steinsalz
PH = PH-Salz (Aethylendiamindinitrat)
Penta = Pentaerythrit
Hex = Hexogen

EXHIBIT O-3

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MILITARY POWDERS AND EXPLOSIVES - PRODUCTION PLANT

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sive) 15.9	Hexogene (High Explosive) 1.7	Phlegmatiser for Explosives 85.0	Phlegmatiser Explos
1.2			
als 12.8	Acetylcellulose	Lubricating grease	Explosives f
d 8.8	quality Artif Silk 32.5	(party Army) 11.0	Civil purpose
ture) 7.7	Acetone 24.3	Miscell 4.0	(nitrogene
	Plasticizers and Solvents 16.3		Special requi
ral) 7.5	Plastics 7.7		ments for Arm
der 3.3	Pharmaceuticals & perfumes 3.0		Textile Special
oride	Other Chem Ind 4.7		Lubricating o
1.9			Cerusin Wax
Alkali 1.8	Preserving 0.1		Other Chem Ind
Inorgan	Other Industries 2.4		
ands 14.7	Export 1.3		
1.6	% 100.0		
ol. 4.8			
4.3			
ol.			
6.6			
2.1			
100.0			

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COMPOSITION OF GERMAN EXPLOSIVE AND POWDER MIXTURES

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EXHIBIT Q

Flake - Powder for Howitzers.

a) for Propellants

1) 35.80% Diglykol
63.65% Nitrocellulose (N = 13%)
0.50% Akardit
0.05% Magnesiumoxyd

2) 44.50% Diglykol
54.40% Nitrocellulose (N = 13%)
0.50% Akardit
0.05% Magnesiumoxyd
0.05% Graphit
0.50% K_2SO_4

3) 31.12% Diglykol
38.03% Nitrocellulose (N = 13%)
30.00% Nitroguanidin
0.50% Akardit
0.10% Graphit
0.25% Magnesiumoxyd

b) for primary charges

4) 44.37% Nitroglycerin
54.23% Nitrocellulose (N = 13%)
1.30% Akardit
0.05% Magnesiumoxyd
0.05% Graphit

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EXHIBIT Q

Macaroni - Powder for Gune (Nitroidin - Base)

a) Powder for 750 Calories for 8.8 cm Flak 41 H.E. Shell.

18.64 % Diglykoldinitrat
43.51 % Nitrocellulose (N = 12%)
30.00 % Nitroguanidin
3.75 % Aethylphenylurethan
3.25 % Diphenylurethan
0.25 % Magnesiumoxyd
0.10 % Graphit
0.50 % Akardit

b) Powder with 730 Calories for 8.8 cm Flak 41 Armor Piercing.

16.92 % Diglykoldinitrat
39.48 % Nitrocellulose (N = 12%)
30.00 % Nitroguanidin
5.00 % Aethylphenylurethan
4.25 % Diphenylurethan
0.25 % Magnesiumoxyd
0.10 % Graphit
4.00 % ENO_3

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POWDER, EXPLOSIVES AND
RELATED PRODUCTS

EXHIBIT Q

Macaroni - Powder for Guns (extruded) (Diglycole-Base).

a) Powder with 825 calories for 8.8 cm Flak 18 and s.10 cm k 18.

29.00 % Diglykol
67.65 % Nitrocellulose (N = 12%)
3.00 % Centralit
0.25 % Magnesiumoxyd
0.10 % Graphit

b) Powder with 870 calories for 3.7 cm Flak and 3.7 cm Flak.

29.23 % Diglykol
68.22 % Nitrocellulose (N = 12%)
1.70 % Centralit
0.50 % Akardit
0.25 % Magnesiumoxyd
0.10 % Graphit

c) Powder with 700 calories, none Flashless, for s.F.H.18.

26.72 % Diglykol
62.33 % Nitrocellulose (N = 12%)
8.00 % Centralit
1.80 % Vaseline
0.80 % Phthelate
0.25 % Magnesiumoxyd
0.10 % Graphit

d) Do Flashless for s.10 cm K 18.

26.37 % Diglykol
61.53 % Nitrocellulose (N = 12%)
7.50 % Centralit
1.60 % Vaseline
0.65 % Phthalate
0.25 % Magnesiumoxyd
0.10 % Graphit
2.00 % K_2SO_4

e) Powder with 730 calories for 8.8 cm Flak.

27.17 % Diglykol
64.08 % Nitrocellulose (N = 12%)
5.35 % Centralit
1.55 % Vaseline
0.90 % Phthalate
0.25 % Magnesiumoxyd
0.10 % Graphit

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New - Powders (to utilize the waste materials).

a) Powder with 730 calories for 8.8 cm Flak and other guns.

14.83 % Diglkoldinitrat
69.92 % Nitrocellulose (N = 12%)
10.00 % Dinitrotoluol
2.00 % Alphanitronaphthalin
3.00 % Centralit
0.15 Magnesiumoxyd
0.10 % Graphit

b) Powder with 730 calories for all important guns.

25.95 % Diglykoldinitrat
60.55 % Nitrocellulose (N = 12%)
3.00 % Hydrocellulose
4.00 % Dinitrotoluol
2.50 % Alphanitronaphtalin
3.75 % Centralit
0.15 % Magnesiumoxyd
0.10 % Graphit

c) Powder with 720 calories for all kinds of guns.

18.85 % Diglykoldinitrat
44.00 % Nitrocellulose (N = 12%)
20.00 % Nitroguanidin
3.50 % Dinitrotoluol
2.00 % Alphanitronaphthalin
1.50 % Aethylphenylurethan
1.50 % Diphenylurethan
0.40 % Akerdit
4.00 % Hydrocellulose
0.15 % Magnesiumoxyd
0.10 % Graphit
4.00 % ENO_3

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Rockets - Munition

1) Powder with 900 calories for all Mortars.

35.33 % Diglykoldinitrat
60.17 % Nitrocellulose (N = 12.60%)
1.50 % Hydrocellulose
1.40 % Aethylphenylurethan
1.00 % Diphenylurethan
0.35 % IG-Wachs E
0.25 % Magnesiumoxyd
0.80 % KNG_3

2) Powder with 865 calories for 30 cm Mortars.

34.62 % Diglykoldinitrat
59.03 % Nitrocellulose (N = 12.60%)
3.00 % Hydrocellulose
1.90 % Aethylphenylurethan
0.50 % Vaseline
0.50 % Akardit
0.25 % Magnesiumoxyd

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EXHIBIT Q

Macaroni Powder for Navy Guns.

a) Powder with 820 calories for important Navy Guns.

25.27 % Diglykoldinitrat
69.38 % Nitrocellulose (N = 12.2%)
5.00 % Centralit
0.25 % Magnesiumoxyd
0.10 % Graphit

b) Powder with 730 calories for important Navy Guns.

23.87 % Diglykoldinitrat
65.63 % Nitrocellulose (N = 12.2%)
9.00 % Centralit
1.25 % Phthalate
0.25 % Magnesiumoxyd
0.10 % Graphit

c) Do, to save Centralite, by replacement with Alphanitronsphthalin.

23.94 % Diglykoldinitrat
65.71 % Nitrocellulose (N = 12.2%)
7.00 % Alphanitronaphthalin
2.50 % Centralit
0.50 % Akardit
0.25 % Magnesiumoxyd
0.10 % Graphit

d) Powder with 650 calories propellants for Star shells.

25.10 % Triglykol
58.55 % Nitrocellulose (N = 12.2%)
12.00 % Centralit
0.25 % Magnesiumoxyd
0.10 % Graphit
4.00 % K_2SO_4

e) Powder with 820 calories for 3.7 cm SKC/32.

21.75 % Diglykoldinitrat
35.50 % Nitrocellulose (N = 12.2%)
40.00 % Nitroguanidin
0.50 % Akardit
0.70 % Aethylphenylurethan
0.70 % Diphanylurethan
0.25 % Magnesiumoxyd
0.10 % Graphit
0.50 % K_2SO_4

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f) Powder with 730 calories for most important Navy Guns.

18.20 % Diglykoldinitrat
42.45 % Nitrocellulose (N = 12%)
25.00 % Nitroguanidin
4.50 % Diphenylurethan
4.50 % Aethylphenylurethan
0.25 % Magnesiumoxyd
0.10 % Graphit
5.00 % K_2SO_4

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FLOW SHEET OF EXPLOSIVES PRODUCTION

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FLOW SHEET OF TNT PRODUCTION (3 SHEETS)

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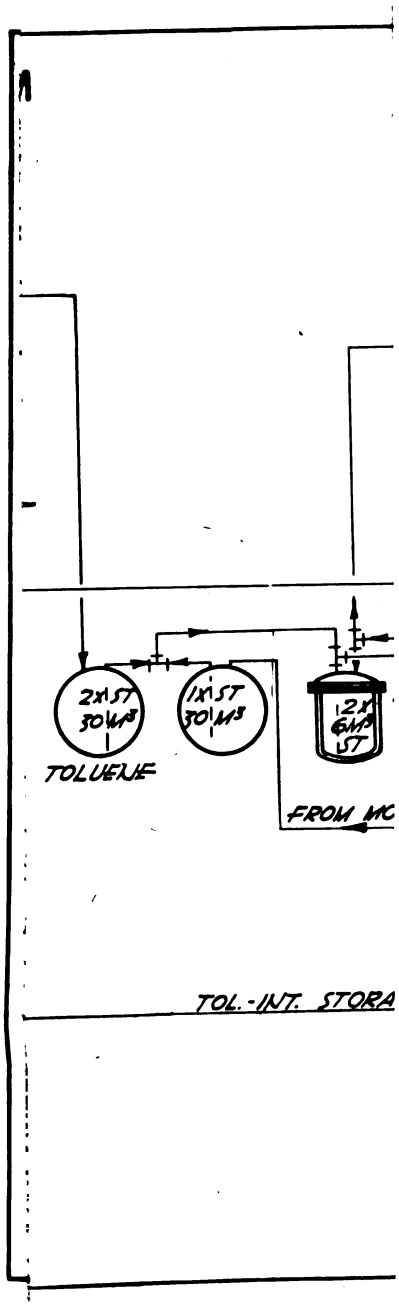

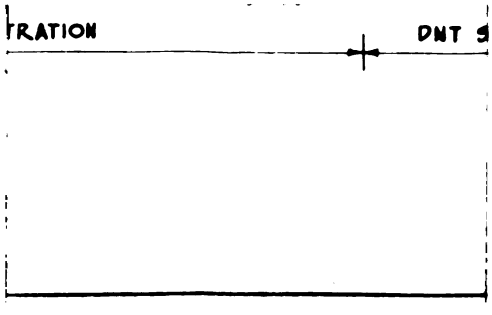

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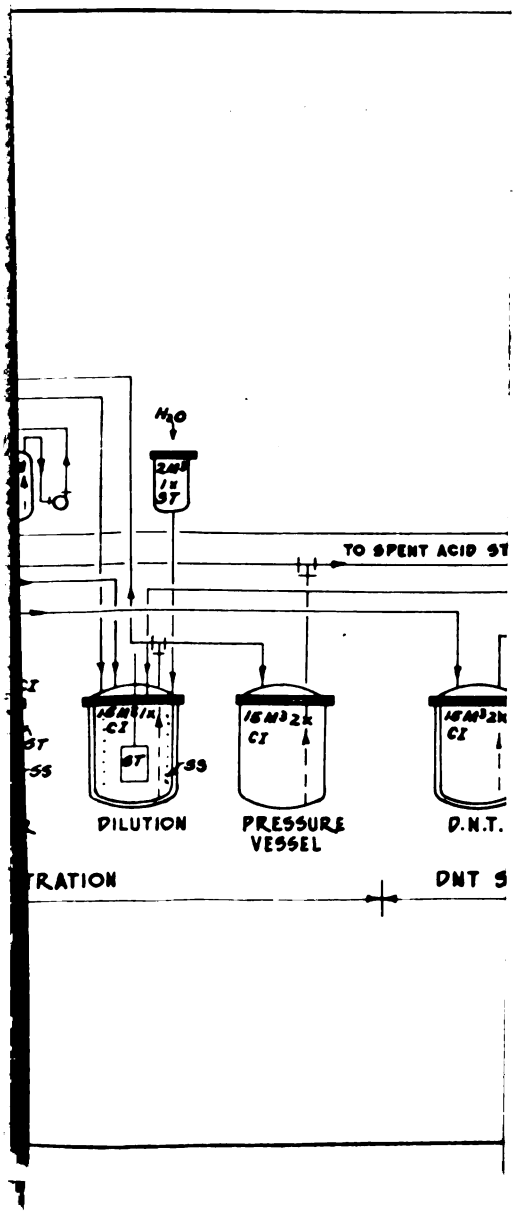

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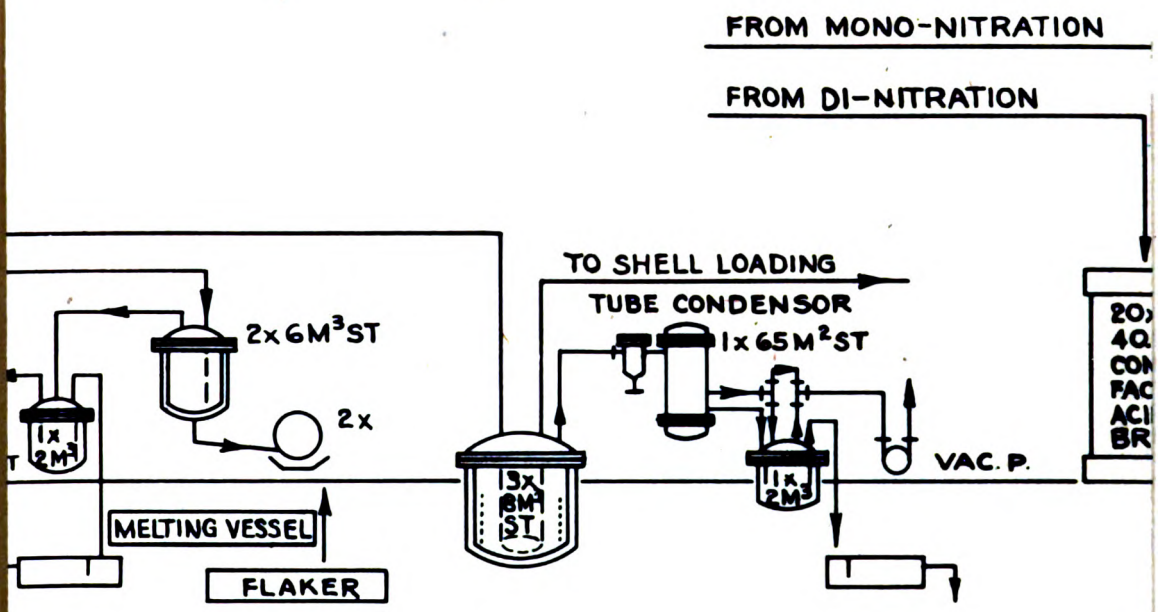

ANULATION | STORAGE FOR LIQUID TNT | SPENT A

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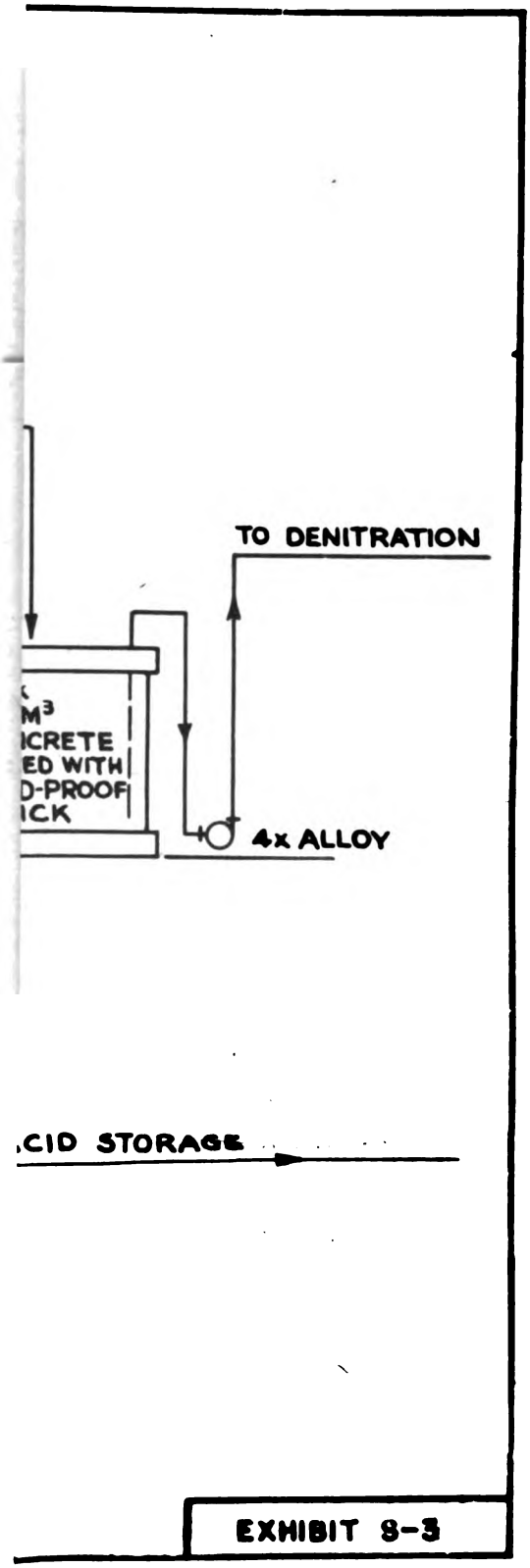

EXHIBIT S-3

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FLOW SHEET OF TNT PRODUCTION WITH BLANKET

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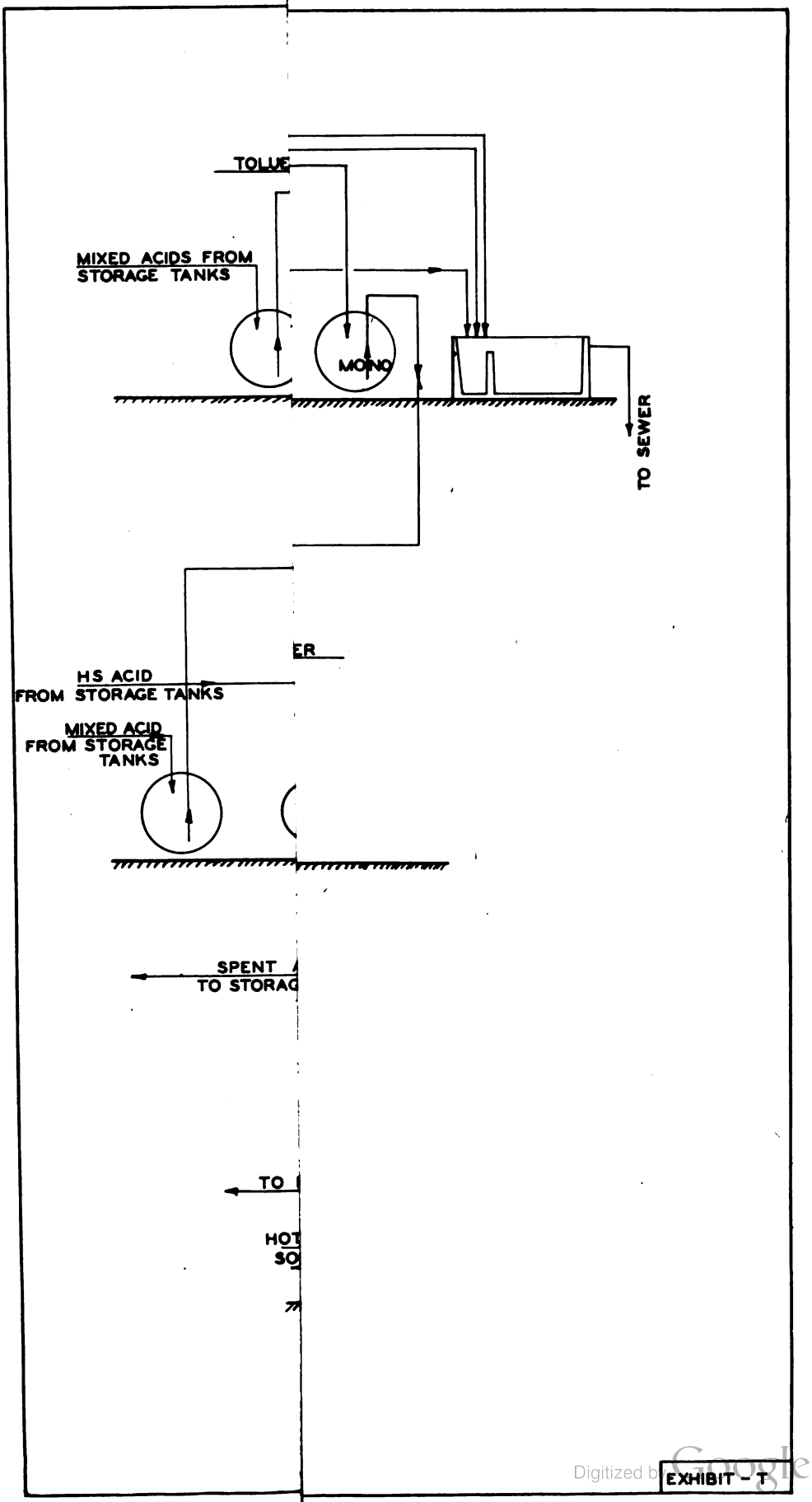

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EXHIBIT - T

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FLOW SHEET OF TNT PRODUCTION IN KRUMMEL PLANT

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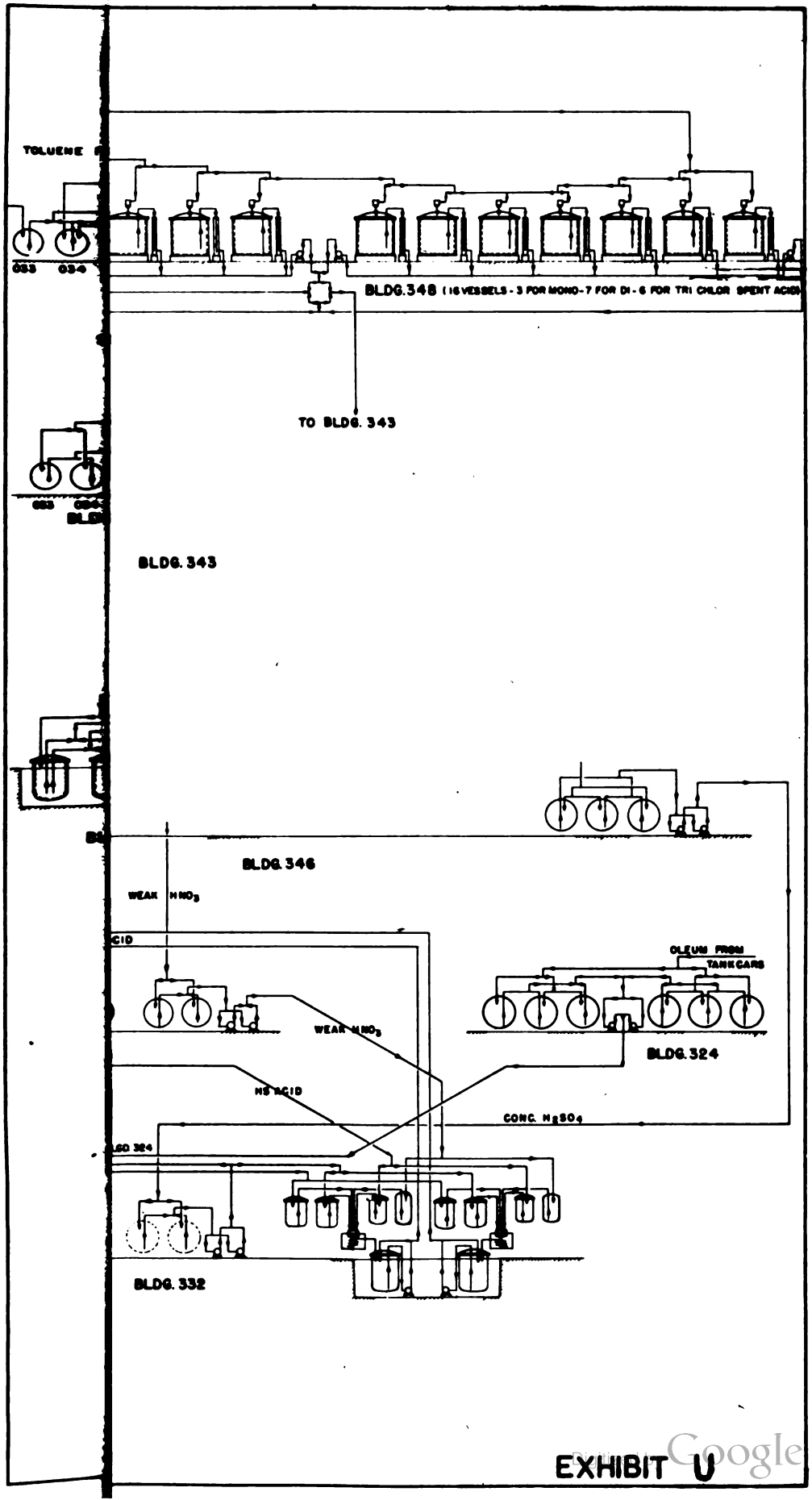
TOLUENE
BLDG. 348 (16 VESSELS - 3 FOR MONO - 7 FOR DI - 6 FOR TRI CHLOR SPENT ACID)
TO BLDG. 343
BLDG. 343
BLDG. 346
WEAK HNO_3
OLEUM FROM TANK CARS
BLDG. 324
WEAK HNO_3
CONC. H_2SO_4
BLDG. 332

EXHIBIT U

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STANFORD UNIVERSITY

ORGANIZATION FOR WAR GAS (K-STOFF OR C-STOFF) PROGRAM

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EXHIBIT "CA"

Chemical Plants owned by the Government

(Status at the beginning of 1945)

1) In accordance to the military necessities the Reichsministerium fur Rüstung und Kriegsproduktion (state department of war supply) gives the permit for planning and construction of the plants.

2) The order to build up the plants, the money and the final settlement are given by the Oberkommando des Heeres, Heereswaffenamt (WaA) as follows: Plants for powder and explosives by the department Mun 3, all other chemicals by the department Mun 6.

3) Supervising, assignment of building materials, metals and manpower are done by the Beauftragter fur den Vierjahresplan (G.B.Chemie) according to the directions of the state department of war supply.

4) The completed plants are handed over by the WaA to the Montan-Industriewerke GmbH which is owned by the OKH. Montan leases the plants to private firms, which found subsidiaries in order to operate these plants.

One supplement

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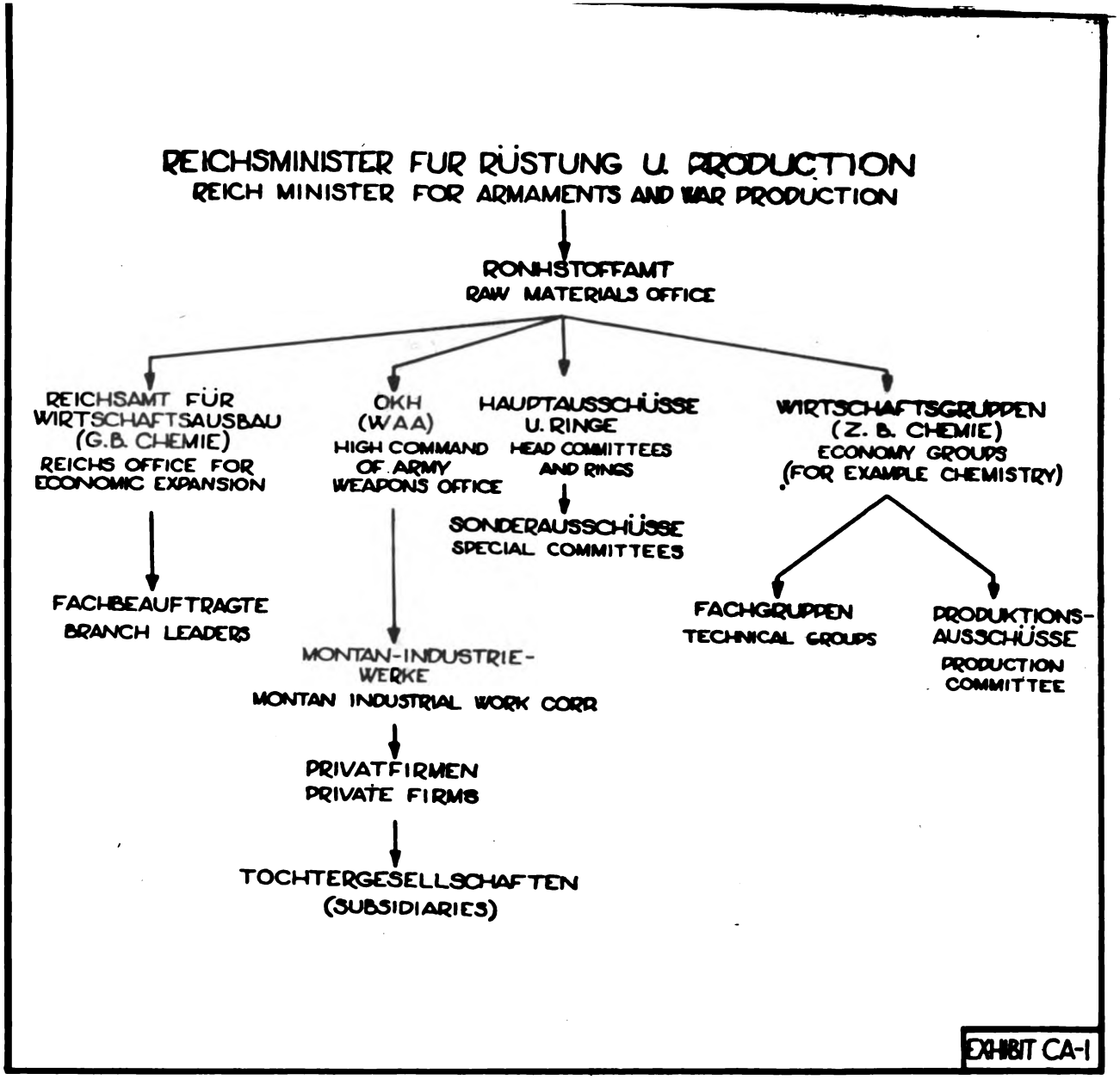

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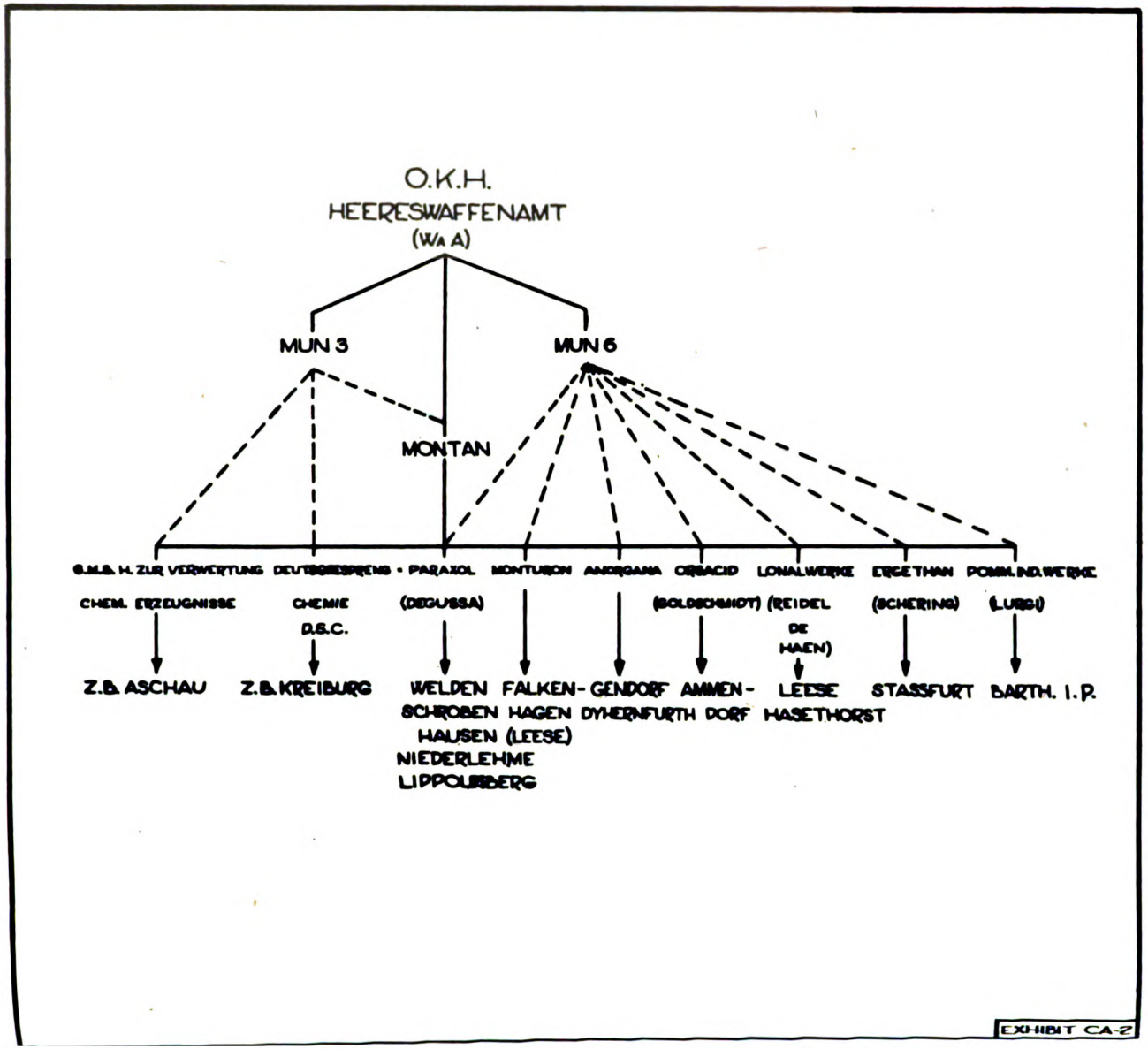

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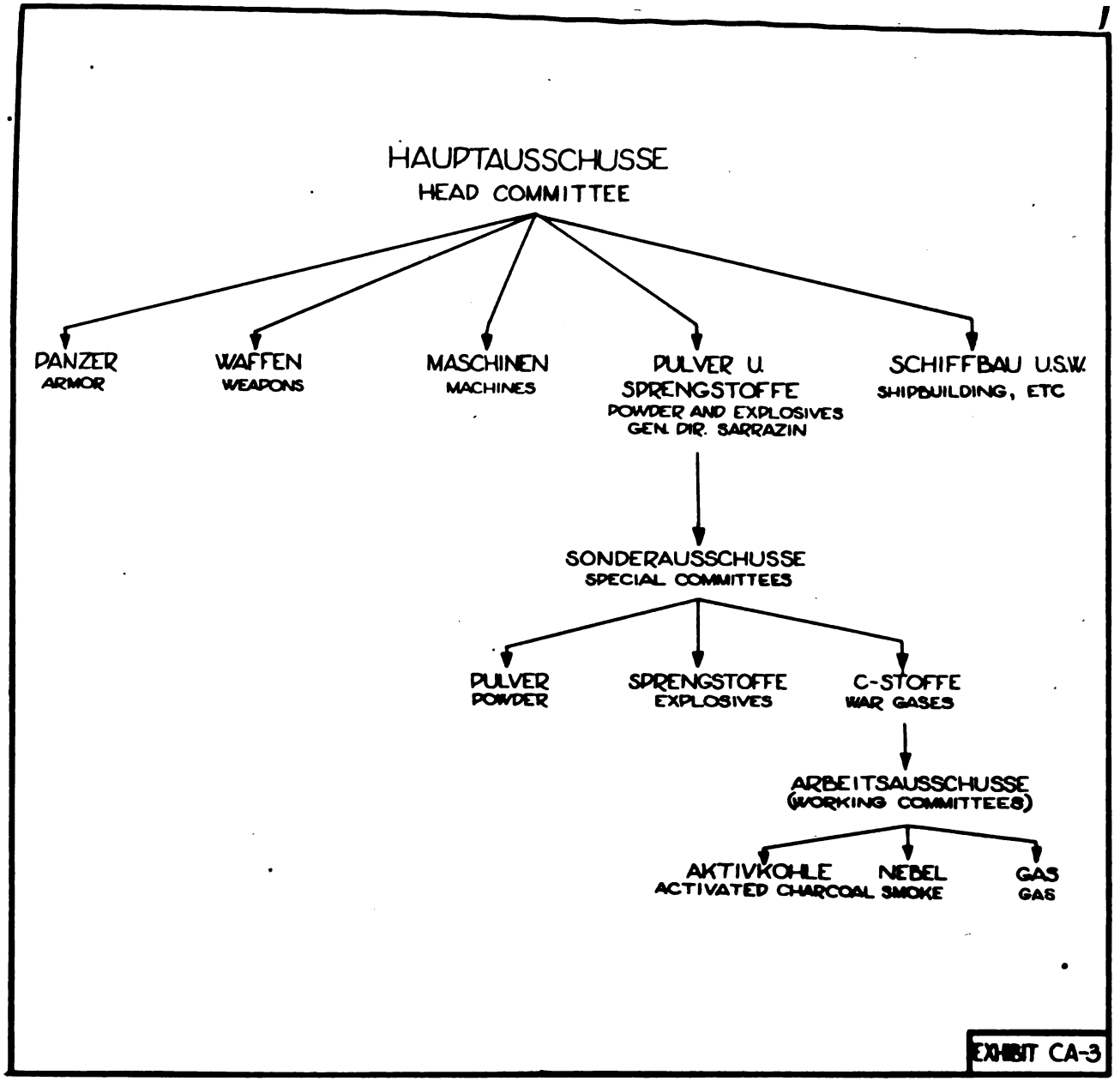

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COMPARISON OF GAS PRODUCTION CAPACITY

ACTUALLY COMPLETED 1939-1942

WITH THAT PLANNED IN 1938

Digitized by Google

K-STOFFE

COMPARISON OF WAR GAS CAPACITY PLANNED AUG. 15, 1936 WITH CAPACITY ACTUALLY REACHED AND THE CAPACITY PLANNED IN SEPTEMBER 1941 WITH THE PRODUCTION SITUATION IN SEPTEMBER 1941

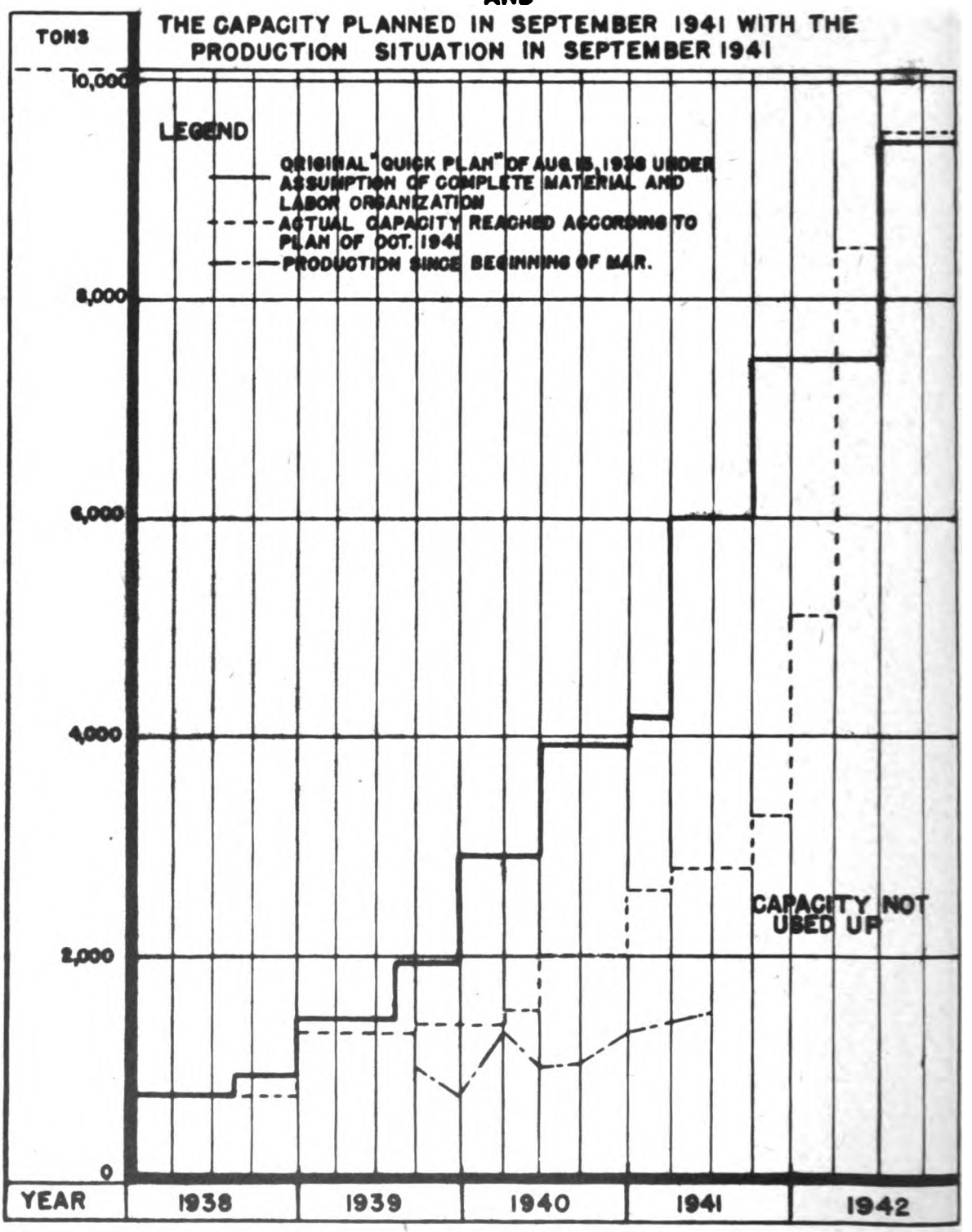

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EXHIBIT - CD

RAW MATERIALS FOR THE PRODUCTION OF WAR GASES

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Geheime Kommandosache!

1.) [illegible]

2.) [illegible]

3) [illegible]

4.) [illegible]

Ausgangsmaterialien
für die Herstellung aller G Stoffe in t
für je 100 t Endprodukte

	Gelb	A-Oel	Anin	Oel P	Tabun	Sarin I	Sarin II	O L	D-Lost	P G
Aethylat									54	
Acetophenon	92									
Anilin ✓		77								
Ammoniak lose					25					28,4
Arsenik ✓		49	48							
Athylenchlorid									4	
Athylenoxyd										98,3
Bisulfitlauge 25%		250								
Calciumchlorid ✓	211									
Chlor			32	39		166	145	217	50	128
Chlorbenzol					20					
Cyannatrium					50					
Diphenylamin			65							
Eisen ✓	55									
Essigester		20								
Flusssäure							20			
Isopropylalkohol						95	90			
Kalk ✓	21							185		46
Kochsalz		185								
Kohlenoxyd				62						49,8
Methanol	21				60	166	160			
Natrium						32				
natriumchlorid ✓	46									
Natriumfluorid						97				
Natriumnitrit		61								
Natronlauge					15	70			5	20
Oleum 65%										130
Phosphoroxychlorid					134					
Phosphortrichlorid						220	210			
Salzsäure lose	28	60								15
Silber		20								2

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EXHIBIT CC-1

Anzeigenkombination
für die Herstellung von Stoffe in 4
für je 100 l Endprodukte

		O-Salz	A-Säure	Amin		Öl P	Tallöl	Harzin I	Harzin II	O L	B-Lack	P G
Sprit							35,5			100		
Schwefel										70,5	22	25
Schwefeldioxyd												60
Schwefelsäure							15				1	
Wasserstoff				0,95						3,6	1	

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EXHIBIT CC-2

Übersicht über die C-Stoffproduktion — Tabelle II

Entgiftungsmittel — Alles in Kato — Stand: 1.8.44

1	2	3	4	5	6	7	8	9	10	11	12
Produkt	Produktionsstätte	Produktion augenblicklich	Produktion z.Zt. mögl.	Produktion voll	Produktion voll ab	Planzahl ges.	ges.	Forderungen d. Wehrmacht	Forderungen LS I	Forderungen LS II u. III	Vorprodukte bed. Chlor
Entg.-Stoff 4o	Wolfen	2o	2o	4o	1. 10.44	4o	89	4o	-	-	2o
WKM.	Wolfen	4o	5o	5o	sofort	18o	4oo	4oo	-	-	73
	Döberitz	-	-	13o	1. 1.45						19o
Rosantin	Bitterfeld	42o	8oo	8oo	sofort	8oo	1 15o	1 ooo	15o	-	56o
Hautentg.Salbe +)	Schwarzkopf	49o	7oo	7oo	sofort	1 748	3 ooo	3 ooo			
	Kleinol	81o	1 ooo	1 ooo	sofort			+ 225 t			
	Sunlicht, Mhm.	384	6oo	6oo	sofort						
	Mülhens	-	43o	43o							
Na-Bisulfat	Höchst	9o	1oo	2oo		1 33o	2 3oo	1 ooo	1 ooo	3oo	
	Frose	-	1oo	2oo	1. 1.45						
	Fahlberg-List	29o	75o	75o	sofort						
	Pressburg DAG	69	12o	12o	sofort						
	Anh.Salz	-	6o	6o	sofort						
Chlorkalk	Bitterfeld	45	12o	12o	sofort	4 39o	1o 56o	8 ooo	1 56o	1 ooo	2 8oo
	Zscherndorf	222	54o	54o	sofort						
	Ammendorf	57	15o	15o	1. 9.44						
	Osternienburg	24o	4oo	4oo	1.11.44						
	Westeregeln	217	48o	5oo	1. 9.44						
	Aussig	239	3oo	6oo	sofort						
	Rheinfelden	138	45o	45o	1. 9.44						
	Knapsack	34	4o	8o	1.1o.44						
	Tann	147	15o	3oo	1.11.44						
	Burghausen	23	15o	15o	1. 9.44						
	Hallein	97	4oo	4oo	1.1o.44						
	Jaworzno	4	9o	12o	1.1o.44						
	Zombkowitz	224	28o	28o	sofort						
	Moscice	18o	18o	3oo	1.11.44						

Erläuterungen:

Zu Spalte 6: Hierfür gilt dasselbe wie das für Spalte 6 in Tabelle I Gesagte.

+) Zu Spalte 1o u.11: Alle Zahlen in 1 ooo Stck. Taschenbehältern zu 42 g Inhalt. Die Forderungen des zivilen Luftschutzes sind erteilt in Bedarfe für Luftschutzorte erster und Luftschutzorte 2. und 3.Ordnung.

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EXHIBIT CC-3

Geheime Kommandosache Anlage zu der RLM/Abt/WW g.Kdos. [illegible] g. Kdos.

Übersicht über die C'-Stoffproduktion

Tabelle I

C-Stoffe — Alles in Mato — Stand: 1.8.44

1	2	3	4	5	6	7	8	9	10	11	12	13
Produkt	Produktionsstätte	Produktion				Planzahl	Forderungen d.Wehrmacht	Vorproduktenbed.		Arbeiterbedarf		
		augenblicklich	z.Zt. mögl.	voll	voll ab	ges.		Chlor	sonst.	Bau	Mont.	Betrieb
O - Salz	[illegible]	∅	∅	9o	4.1o.44	71o	569	366	673 Acetophenon	-	-	18
"	Seelze	∅	12o	12o	sofort					-	7	68
"	Hahnenberg	∅	25o	5oo	1.1o.44					19	111	496
Arsin-Öl	Staßfurth	15o	27o	27o	sofort	4oo	4o1	41o	51o Anilin 18? Arsenik	-	-	191
"	Leese	∅	4oo	4oo	1.1o.44					-	-	37o
C 1, 2	Haselhorst	6o	15ß	15ß	sofort	15ß	1o2			-	-	146
C 1	Leese	∅	∅	12o	1. 3.45					-	-	13o
Asin	Urdingen	9o	2oo	2oo	sofort	2oo	428		13o Diphenylamin 96 Arsenik	-	3	7o
Öl P	[illegible]	∅	29o	29o	1. 9.44	1 4oo	1 498	1 o16		-	1	19
"	Wolfen	∅	27o	27o	1. 9.44					-	1	22
"	Urdingen	∅	14o	14o	1. 9.44					-	1	14
"	Aunchwitz	∅	∅	7oo	1. 4.45							
Tabun	Dyhernfurth	7oo	75o	1 ooo	1. .44	1 ooo	1 877	1 15o	5oo Na-Cyanid 3o6 Phosphor	28o	1165	1 917
Sarin	Dyhernfurth	∅	∅	1oo	1. 1.45	6oo	-	2 5o6	455 Phosphor			
"	Falkenhagen	∅	∅	5oo	1. 5.45					152	548	534
GE	Ammendorf	4oo	7oo	7oo	sofort	2 1oo		4 39o	495 Schwefel 1315 Aethylenoxyd	-	-	366
"	(Hüls)	∅	6oo	6oo	1.1o.44		5 e24			-	-	96
"	(Bendorf)	∅	5oo	8oo	1.1o.44					-	-	14o
GE	Gendorf	5oo	1 ooo	4 ooo	1. 9.45	4 ooo		2 ooo	92o Schwefel	39o	358	162
CKM	Ammendorf	2oo	5oo	5oo	sofort	5oo	4o2					
Q 9	Ammendorf	5o	5o	1oo	1.11.44	1oo	116	15o	17o Aethylenoxyd			
T 15o	Dyhernfurth	∅	1oo	2o	sofort	2o	13					
T 155	Dyhernfurth	∅	1oo	2o	sofort	2o	8,5					

Erläuterungen:

Zur Spalte 1 u. 2: CKM kann nur dann imA'dorf hergestellt werden, wenn dafür die OL-Herstellung stillgelegt wird.

" " 3: Die Zahlen stellen die tatsächliche Produktion in den letzten Monaten oder bei dem anlaufenden Werk Dyh. die letzte Monatsproduktion dar.

" " 6: X Die in dieser Spalte angegebenen Daten zeigen, zu welcher Zeit eine Vollproduktion möglich ist, wenn ab 1.8. mit der Unterstützung, die vom Sonderausschuss C immer wieder gefordert wird ist, und sich auf Materialbeschaffung und Arbeiterfrage bezieht, gerechnet werden kann.

" " 9 u.1o: Bei dem Chlor- und Phosphor-Bedarf für Tabun und Sarin ist die Koppelung der beiden Fabrikationen berücksichtigt. (Seite 2).

" " 11 bis 13: Die Arbeiterbedarfe für die Produktion CKM und Q 9 sind schon bei OL A'dorf, die für T 15o, T 155 und Sarin bei Tabun Dyh. berücksichtigt.

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EXHIBIT CC-4

Geheime Kommandosache!

Anl. zu: RLA/ 492/44

Anlage 4 zu Ch H Mitt u.Bfl/Stab III 6 Nr. 1200/44 g.Kdos.

Übersicht über den Stand der Bevorratung u.Fertigung an Kampfstoffgeschossen u. -bomben

Lfd. Nr.	Geschoß- bzw. Bombenart	Stand der Bevorratung (in Stück) a) Soll = Forderung des Gen St. (Heer und Luftwaffe)	b) Ist = vorhandene Bevorratung 1) erfüllte Geschosse bzw. Bomben	2) unerfüllte Geschosse bzw. Leerkörper	3) gesamt (Sp. 4+5)	4) % der Forderung	a) Fehl an Bevorratung (Sp.3 - 6)	b) % der Forderung	Monatsfertigung(in Stück) Bevorratungsforderung a) s.Zt. durchgeführt	b) die vorhandenen Vollmunitionen möglichst erstellt (ohne Kammerhülsen) +)	b) wird erfüllt in Monaten bei einer Fertigung im Monat	nach Sp.10	nach Sp.11	Monatsmaschinenbedarf (Stück) Forderung der Generalstäbe	wird gedeckt in % bei einer Fertigung nach Sp. 10	wird gedeckt in % bei einer Fertigung nach Sp. 11	Bemerkungen
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		17	
A	Bezeichnung																	
1	15 cm Jgr. 38 Sh.	240 000	10 042	–	10 042	4	229 950	96	–	30 000	3		8	40 000	75			
2	15 cm Jgr. 38 Sh	810 000	738 626 1)	37 697	776 323	96	33 677	4	25 000	135 000	7	2	1	135 000	100		1) einsch 148 000 Stk 19 Sh.	
3	15 cm Jgr. 38 Sh	2 550 000	886 707 2)	831 789	1 718 496	67	831 504	33	100 000	425 000	9	2	2	425 000	100		2) einsch 486 707 St 19 Sh.	
4	10 cm Gr. 38 Sh.	42 000	–	42 004	42 004	100	–	0	–	7 000	2	–		7 000	100			
5	10 cm Gr. 39 ZB	126 800	–	26 931	26 931	21	98 069	79	20 000	21 000	3	5	5	21 000	100			
6	15 cm Gr. 38 Sh.	270 000	88 500 3)	20 832	109 332	40	160 668	60	30 000	45 000	6	6	4	45 000	100		3) einsch 70 000 St 19 Sh.	
7	15 cm Gr. 39 ZB	810 000	294 313 4)	105 867	400 180	50	409 820	50	30 000	50 000	4	14	8	135 000	37		4) nur	
8	15 cm Wgr.41 WSh.	240 000	129 083	127 661	256 744	106	–	0	10 000	40 000	4	–	–	40 000	100			
9	15 cm Wgr.41 Sh.	6 000	26 574	41 709	68 283	114	–	0	10 000	10 000	1	–	–	10 000	100			
10	10 cm Wgr.35 Sh.	223 000	157 416	65 742	223 158	100	–	0	–	–	–	–	–	–	–			
11	Spr15bubohse 37	580 000	385 555	461 019	846 574	282	–	0	–	50 000	6	–	–	50 000	100			
B	[illegible]																	
12	[illegible]	–	32 115	17 276	49 391	–	–	0	–	–	–	–	–	–	–			
13	[illegible]	18 000	100	16 086	16 186	90	[illegible]	10	1 100	3 500	6	2	1	2 000	175			
14	[illegible]	900	–	347	347	39	553	61	100	200	3	6	3	100	200			
15	[illegible]	450 000	7 200	40 114	47 314	10,5	402 686	89,5	12 000	30 000	6	33	14	50 000	60			
16	[illegible]	–	57 183	63 920	121 105	–	–	0	–	–	–	–	–	–	–			
17	[illegible]	54 000	–	16 125	16 125	30	37 875	70	2 300	5 000	6	16	8	6 000	83			
18	[illegible]	3 600	–	–	–	0	3 600	100	–	400	6	[illegible]	9	400	100			
19	[illegible]	900	–	786	786	87	[illegible]14	13	200	200	–	1	1	160	200			
20	[illegible]	108 000	76 032	19 119	95 151	88	12 849	12	4 600	14 500	6	3	1	12 000	120			
21	[illegible]	144 000	103 852 5)	85 898	189 750	132	–	0	2 700	16 000	6	–	–	16 000	100		5) einsch 6 436 Kg 250 Gr.	
22	[illegible]	36 000	–	–	–	0	36 000	100	–	–	–	[illegible]	[illegible]	[illegible]	0			
23	[illegible]	–	58 977	[illegible]	120 445	–	–	0	–	–	–	–	–	–	–			
24	[illegible]	54 000	–	2 333	2 333	4	51 667	96	1 100	3 000	6	47	17	6 000	50			

+) Kammerhülsendeckung ist vordringlich hierzu sicherzustellen

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EXHIBIT CC-5

Anl. zu: RLN 52/44 geh.

Anlage 1 zu Chef H Stab u OKH / Stab Stbf XIIIe Nr. 1020/44 geh.

Geheime Kommandosache

ÜBERSICHT ÜBER DEN STAND DER BEVORRATUNG DER TRUPPEN MIT KA-MUNITION

lfd. Nr.	Hauptcalibre	Stand der Bevorratung (in to) a) Erste Forderung der Generalstäbe (Heer u. Luftwaffe)	b) Zweite (endgültige) Bevorratung 1) verfügt (in Geschossen u. Patronen)	2) unverfügt	3) Gesamt (Sp 4+5)	Stand an Munition der Vorderung (Sp. 6)	% der Forderung bis	% der Forderung	Kunstfertigung in to a) mit dem b) in Sp. 8 fertigbaulichen Anlagen möglich	b) in Anlagen (in Bau wird (geplant)	wird erreicht am	Bevorratungsforderung wird erfüllt in Tonnen bei einer Fertigung nach Spalte 10	nach Spalte 11	Munitionsbedarf (monatl.) Forderung der Generalstäbe	wird gedeckt in % bei ebenmäßiger Verteilung nach Spalte 14	Be- mer- ku- ng
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	15 a	
	a) Vorbringer:															
1)	C-Gase (Chlorcyanphosgen)	4 900	4 600	2 300	6 900	140	-	0	710	710	1. 444	-	-	570	105	
	b) Blauringer:															
2)	Adin (Adamsit)	4 000	1 400	2 300	3 700	92	300	8	250	250	1 444	1 ½	1 ½	480	52(+)	
3)	C I (Chlor	900	50	850	900	100		0	170	160	1. 744	-	-	120	133	
4)	A (Arsinöl) (ausgleich durch Gelbringmunition)	4 900	1 700	3 600	5 300	110	-	0	400	400	1. 444	-	-	595	78(+)	
	c) Grünringer:															
5)	K 9 (Stickstoffsenf)	2 050	1 050	600	1 650	80	400	20	50	100	1. 744	8	-	360	39	
6)	T (Phosgen)	13 500	5 700	-	5 700	42	7800	58	700	1 400	1. 143	1.	5½	1 500	93	
7)	Tabun	14 100	6 400	300	6 700	47	7400	53	700	1 000	1. 544	11	7½	1 680	56(+++)	
	d) Gelbringer:															
8)	C + B + CK (Lost)	37 500	20 200	6 900	27 100	72	10400	28	2 100	4000(=)	1. 143	5	2½	4 500	60	2

+) Ausgleich durch verstärkte Bevorratung und Einsatz von C I (lfd.Nr.3)

++) Zum teilweise (als Ersatzstoff zum Winterlost) durch Anthrasenlost ersetzt werden

+++) Der Anlauf von Sarin als Ausgleich für Tabun (geplant 300 mato) muss frühestens erreicht werden.

=) Ausserdem Anlagen für 1 500 mato O vorhanden.

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PLANTS AND THEIR CAPACITIES

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EXHIBIT CD

War Gas Plants

Gas	Location	Capacity (metric tons per month) 4/1/40	4/1/41	12/1/42	1/1/45
Thiodiglycol Mustard (O-L)	Ammendorf (Orgacid)	Huels 900	900	700	750
	(Chem. Werke Huls)	600	1,400	600	650
	Gendorf 'Anorgana)	-	-	900)	800
				)	alternative
				)	
Levinstein Mustard (D-L)	Gendorf (Anorgana)	-	1,000	1,000)	4,000
Nitrogen Mustard (T9)	Ammendorf (Orgacid)	-	-	50	100
Arsinoel (A-Oel)	Hahnenberg-Leese) (Lonal))	-	400	400	400
	Stassfurth (Ergethan)	180	180	180	270
Adamsite (Azin)	Uerdingen (I.G.)	-	-	200	200
Clark (Cl)	Haselhorst (Lonal)	-	-	100	150
	Hahnenberg (In Construction.)	-	-	-	150
Chloracetophenone (Omega Salzi O-Salz)	Ludwigshafen (I.G.)	60	60	90	90
	Seelze (de Haen)	120	120	120	120
	Hahnenberg-Leese (de Hoen)	-	500	550	500
Phosgene (Oel F)	Ludwigshafen (I.G.)	-	-	290	290
	Wolfen (I.G.)	-	-	270	270
	Uerdingen (I.G.)	-	-	130	140
	Auschwitz (in construction.)	-	-	-	(700)
Tabun (Trilon 83-T-83)	Dyhernfurth (Niederwerke)	-	-	1,000	1,000
Sarin (Trilon 46-T46)	Dyhernfurth (Niederwerke)	-	-	-	100
	Falkenhagen (Seewerke) (in construction.)	-	-	-	(500)
Total capacity				9,450	

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EXHIBIT "CD" (contd)

Smaller production planned:

T 150 (CNCl)) 20 tons per month. capacity for each
T 155 (HCN)) available in March 1944.

T 300, which spontaneously generates arsine, was planned with a production capacity of 100 tons per month, but was meantime withdrawn because of its slight importance and lack of raw materials.

The important plants at Gendrof and Dyhernfurth had no flak protection but it was planned to give them smoke protection.

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S BUCH DATA ON WAR GASES (K STOFF)

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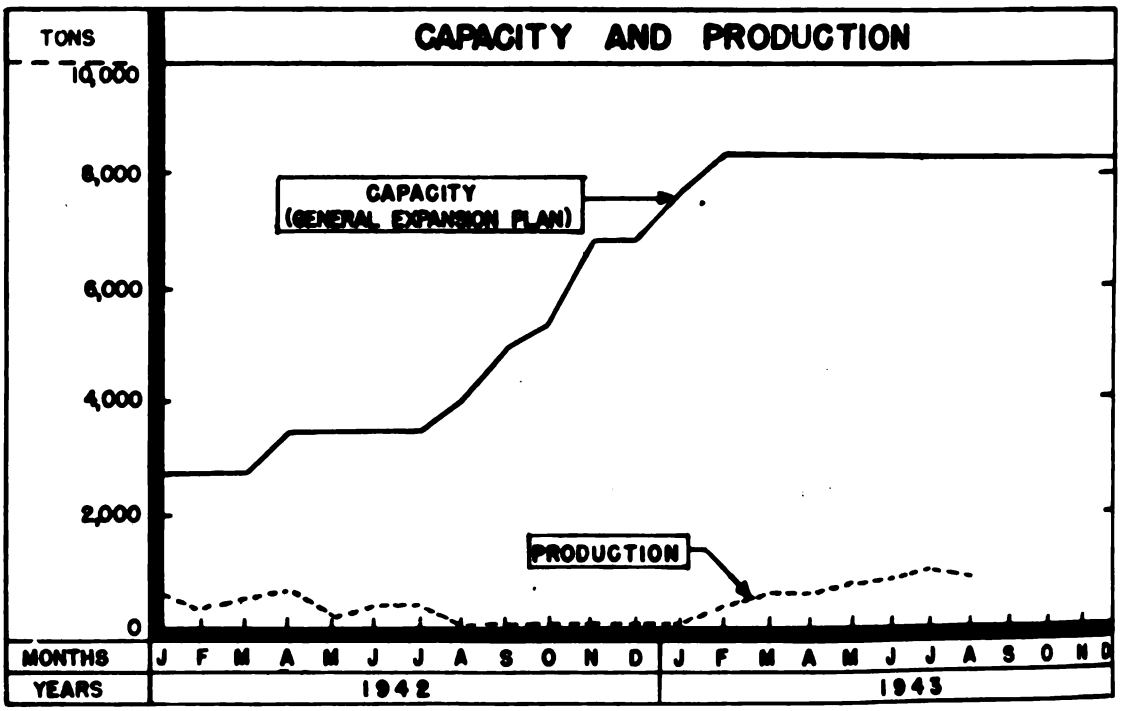
K- STOFFE



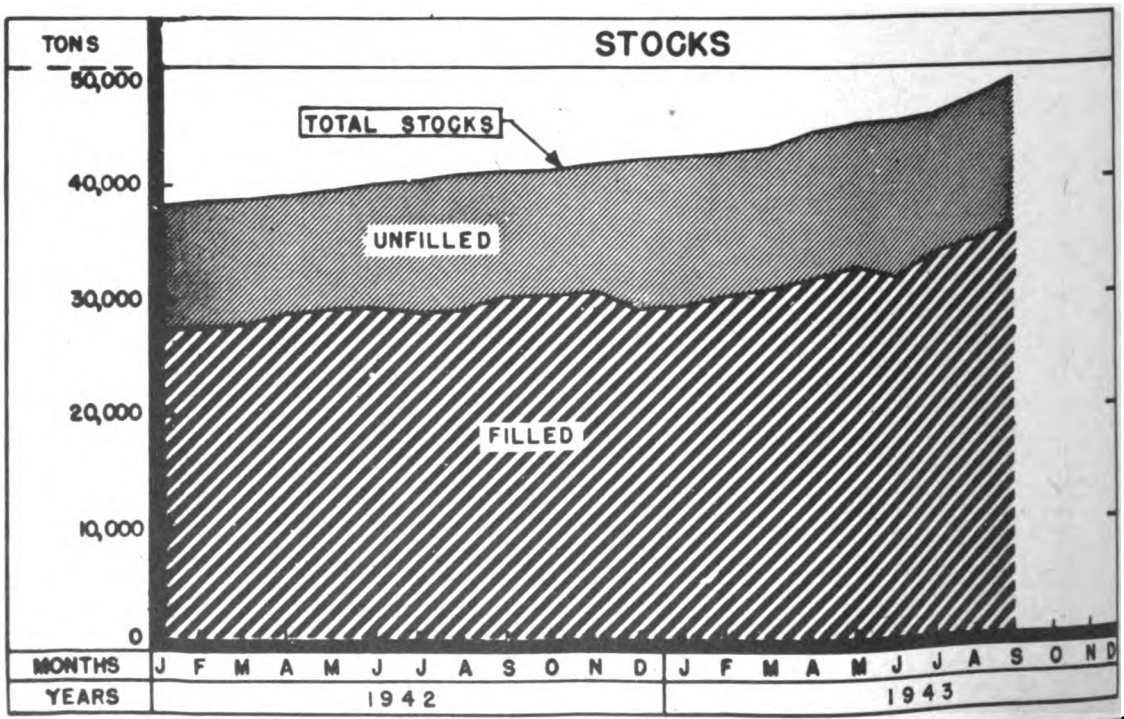


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EXHIBIT-CE

STATUS OF WAR GAS PRODUCTION

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STATUS OF WAR GAS PRODUCTION AND FILLING

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

Blatt Nr.M. 210

EXHIBIT CG

Geheime Kommandosache

32 Ausfertigungen

Stand 1.1.45

Kampfstoff: W e i s e r i n g

in t

(Annaherungswerte)

Monat	Fertigungs-Vorschau Wa A (Ges.Wehrm)	Fertigung Wa A (Ges.Wehrm)	Verpresst oder vergossen (nur Heer)	Abgaben		Bestand X) (unerfullt)
				an Dienststellen ausserhalb d.Fz.In	an andere WT	
Okt 1943	0	0	0	0	0	2 501
Nov	0	0	26	0	10	2 492
Dec	0	0	80	0	0	2 456
Jan 1944	0	0	22	0	0	2 376
Feb	0	0	0	0	0	2 354
Marz	0	0	0	49	0	2 354
April	0	0	0	99	0	2 305
Mai	0	0	0	90	0	2 206
Juni	0	0	0	127	0	2 116
Juli	0	0	0	72	0	1 889
Aug	0	0	0	114	17	1 817
Sept	0	0	0	92	4	1 686
Okt	0	0	0	177	0	1 590

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EXHIBIT CG

Blatt Nr.M 210

Monat	Fertigung Vorschau Wa A (Ges.Wehrm.)	Fertigung Wa A (Ges.Wehrm)	Verpresst oder vergossen (nur heer)	Abgaben		Bestand X) (unverfullt)
				am Dieststellen ausserhalb d.Fz.In	an andere Wt	
Nov	0	0	16	140	0	1 413
Dec	0	0	6	0	0	1 257
Jan 1945	0					
Feb	0					
Marz	0					
April	0					
Mai	0					
Juni	0					

Erlauterungen fur den Berichsmanat

X) Angaben uber Weissring Mun.6 Bestande

siehe: Blatt Nr. M 220 (le.IG.18)

Blatt Nr. M 222 (le.F.H.)

Blatt Nr. M.233 (s.F.H.)

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

Blatt Nr.M 211

EXHIBIT CC

Kampfstoff: B l a u r i n g

in t

Geheime Kommandosache
32 Ausfertigungen

Stand 1.1.45

(Annaherungswerte)

Monat	Fertigungs-Vorschau Wa A 1) (Ges.-Wehrm)	Fertigung Wa W (Ges.Wehrm)	verpresst oder vergossen (nur Heer)	Abgaben		Bestand X) (unverfullt)
				an Dienststellen ausserhalb d.Fz.In	an andere WT	
Okt 1943	140	172	34	2	87	6 617
Nov.	140	137	23	3	29	6 666
Dec.	140	126	0	0	88	6 688
Jan. 1944	140	85	23	1	140	6 870
Febr.	140	178	10	3	233	6 791
Marz.	140	211	37	4	81	6 711
April	140	331	112	0	0	6 799
Mai	110	52	181	3	10	7 018
Juni	110	198	128	76	0	6 958
Juli	110	183	10	4	0	6 870
Aug.	150	191	22	2	134	6 982
Sept.	100	63	31	138	313	7 016
Okt.	50	180	0	100	320	6 597

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Monat	Fertigungs-Verschau Wa A (Ges.-Wehrm.) 1)	Fertigung Wa A (Ges.Wehrm)	verpresst Oder Vergossen (nur Heer)	Abgaben an Dienststellen ausserhalb d.Fz.	Abgaben In an andere WT	Bestand XX) (unverfullt)
Nov.	50	89	0	51	130	6 357
Dec.	50	33 X)	49	41	329	5 878
Jan. 1945	50					
Febr.	50					
Marz.	50					
April	50					
Mai	50					
Juni	50					

X) Energiemangel

Erläuterungen fur den Berichtsmonat

XX) Augaben uber Flauring Mun.-Bestande
siehe: Blatt Nr. M 223
Blatt Nr. M.225
Blatt Nr.M 234
Blatt Nr.M.246

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

Blatt Nr.M 212

Kampfstoff: G r u n r i n g

EXHIBIT CC

Geheime Kommandosache

in t
(Annaherungswerte)

32 Ausfertigungen
Stand 1.1. 45

Monat	Fertigungs-Vorsohan We A (Ges.-Wehrm.)	Fertigung We A (Ges.Wehrm)	verfullt (nur Heer)	Abgaben an Dienststellen ausserhalb d.Fz.	Abgaben In an andere W T	Bestand X) (unverfullt)
Okt.1943	410	61	25	2	87	3 911
Nov.	350	34	8	3	29	3 858
Dec.	350	20	14	0	0	3 852
Jan. 1944	40	29	23	1	34	4 072
Febr.	40	44	35	4	0	4 043
Marz.	40	36	93	4	81	4 048
April	40	52	168	0	500	3 906
Mai	40	33	79	3	116	3 290
Juni	40	59	172	3	20	3 125
Juli	40	115	74	4	145	2 983
Aug.	200	561	19	4	331	3 073
Sept.	200	628	56	2	498	2 991
Okt.	450	232	11	0	0	2 703

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Monat	Fertigungs-Vorschau Wa A (Ges.-Wehrm.)	Fertigung Wa A (Ges.Wehrm.)	verfullt (nur Heer)	Adgaben an Dienststellen ausserhalb d.Fz.In	Adgaben an andere WT	Bestand X) (unverfullt)
Nov.	500	80	6	7	0	2 924
Dez.1945	500	57	72	3	0	2 991
Jan.	500					2 973
Febr.	500					
Marz.	500					
April	500					
Mai	500					
Juni	500					

Erkauterungen fur den Berichtsmonat

-) Vorpredokte fur Dyglikol eingestzt. X) Angaben uber Grunring Mun.-Bestande

siche: Blatt Nr.M 227, 228, 230 (le.F.H.)

Blatt Nr.M 221 (s.I.G.35)
Blatt Nr.M 237 (s.F.H.)
Blatt Nr.M 242 (15 cm Nb.W.41)

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Blatt Nr. M 213

POWDER, EXPLOSIVES AND RELATED PRODUCTS

EXHIBIT CC

Geheime Kommandosache
32 Ausfertigungen
Stand 1.1. 45

Sonderstoff

in t

(Annahmerungswerte)

Monat	Fertigungs-Vorzchau Wa A (Ges.Wehrm.)	Fertigung Wa A (Ges.Wehrm.)	verfullt (nur Heer)	Abgaben		Bestand (Unterfullt)
				an Dienststeelen ausserhalb d.Fz.In	an andere W	
Okt.1943	420	385	2	6	424	323
Nov.	650	507	23	0	423	270
Dez.	850	561	5	0	610	321
Jan.1944	850	493	91	0	414	267
Febr.	450	666	91	0	528	255
Marz.	500	703	156	0	560	302
April	600	643	272	0	424	299
Mai	650	735	207	0	423	246
Juni	650	794	74	0	737	351
Juli	650	602	122	0	528	334
Aug	650	540	111	0	316	286
Sept.	650	778	238	0	635	399
Okt.	0	750	169	0	528	304
Nov.	0	503	81	0	510	341

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

EXHIBIT CG

Monat	Fertigungs-Vorschau Wa A (Ges.Wehrm.)	Fertigung Wa A (Ges.Wehrm.)	verfullt (nr Heer)	Abgaben		Bestand (unverfullt)
				an Dienststell en ausserhalb d.Fz.In	an andere WT	
Dez.1945	0	312	158	212	0	253
Jan.	0					195
Febr.	0					
Marz.	0					
April	0					
Mai	0					
Juni	0					

Erlauterungen fur den Berichtsmonat

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Exhibit CG

Blatt Nr. H 214

POWDER, EXPLOSIVES AND RELATED PRODUCTS

Kampfstoff: G e l b r i n g

EXHIBIT CG

Geheime Kommandosache

in t

32 Ausfertigungen
Stand 1.1. 45

(Annaherungswerte)

Monat	Fertigungs-Vorschau Wa A (Ges.Wehrm.)	Fertigung Wa A (Ges.Wehrm.)	verfullt (nur Heer)	Abgaben		Bestand x) (unverfullt)
				an Dienststellen	an andere WT ausserhalb d.Fz.In	
Okt.1943	o	197	o	o	o	61
Nov.	o	188	o	o	o	258
Dez.	o	191	o	o	o	446
Jan.1944	o	155	o	o	o	637
Febr.	o	87	o	o	o	792
Marz.	o	187	o	o	o	879
April	o	167	o	o	o	1 066
Mai	o	131	o	o	o	1 233
Juni	12o	125	o	o	o	1 364
Juli	12o	o	o	o	o	1 489
Aug.	o	o	o	o	o	1 489
Sept.	o	o	o	o	o	1 489
Okt.	o	o	o	o	o	1 489

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Kampfstoff: G e l b r i n g

EXHIBIT CG

Geheime Kommandosache

in t

32 Ausfertigungen
Stand 1.1. 45

(Annaherungewerte)

Monat	Fertigungs-Vorschau We A (Ges.Wehrm.)	Fertigung We A (Ges. Wehrm.)	verfullt (nur Heer)	abgaben		Bestand x) (unverfullt)
				an Dienststellen ausserhalb d.Fz.In	an andere WT	
Okt. 1943	o	197	o	o	o	61
Nov.	o	188	o	o	o	258
Dez.	o	191	o	o	o	446
Jan.1944	o	155	o	o	o	637
Febr.	o	87	o	o	o	792
Merz.	o	187	o	o	o	879
April	o	167	o	o	o	1 o66
Mai	o	131	o	o	o	1 233
Juni	12o	125	o	o	o	1 364
Juli	12o	o	o	o	o	1 489
Aug.	o	o	o	o	o	1 489
Sept.	o	o	o	o	o	1 489
Okt.	o	o	o	o	o	1 489

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

Blatt Nr.M 214

EXHIBIT CC

Monat	Fertigungs-Vorschau Wa A	Fertigungs Wa A (Ges. Wehrm.)	verfullt (nur Heer)	Abgaben an Dienststellen ausserhalb d.Fz.In	Abgaben an andere W T	Bestand x) (unverfullt)
Nov.	0	0	0	0	0	1 489
Dez. 1945	0	0	0	0	0	1 489
Jan.	0					1 489
Febr.	0					
Marz.	0					
April	0					
Mai	0					
Juni	0					

Erlauterungen fur den Berichtsmonat

x) Angaben uber Gelbring Mon.-Bestande

siehe: Blatt Nr.M 231 (le.F.H.)
Blatt Nr.M 235a(s.F.H.)
Blatt Nr.M.239 (le cm NB.W.35)
Blatt Nr.M.241 (15 cm Nb.W.41)
Blatt Nr.M.244) Sprubbuches 37
Blatt Nr.M.245)

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TOTAL PRODUCTION OF VARIOUS WAR GASES

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Exhibit C H

POWDER, EXPLOSIVES AND RELATED PRODUCTS

Gas production

The whole amount of Chemical Warfare products (filled up into bombs or shells resp.stored in tanks or other containers) was approximately 62,000 tons, from which probably about 13,000 tons were not yet used. The greatest part of the production was filled up into bombs.
The money invested in gas producing plants amounts to about 200 million mark.

Type	whole production (Storage enclosed) tons	Storage (not yet used) tons	producing firm	plant	plant owned by	remarks
Chloreacetophenone	7,000	2,000	Riedel de Haen	Hannover-Seelze	firm	the money for making possible the production was given by OKH
Adamsite	3,000	1,000	I.G.	Uerdingen	firm	
Phosgene	5,000	--	I.G.	Wolfen	Montan(OKH)	only filled up into bombs
Arsineil	7,000	3,000	Ergethan	Staßfurt	Montan(OKH)	
Clark	1,000	900	Lonal	Berlin-Haselhorst	Montan(OKH)	
Mustard gas (Thiodiglycols)	22,000	2,000	Orgacid	Ammendorf	Montan (OKH)	about 250 tons produced in Huls for experimental reasons
Mustard gas (direct)	3,000	3,000	Anorgana	Gendorf	Montan(OKH)	including 600 tons of bad quality
T 9 (HN3)	2,000	1,000	Orgacid	Ammendorf	Montan(OKH)	
Tabun	12,000	--	Anorgana	Dyhernfurt	Montan(OKH)	
Sarin	--	--				
	62,000	12,900				

Besides these mentioned quantities there have been stored in German about 2,000 tons gas of different types of foreign origin such as Italian, French, Polish and Jugoslavian before the German troops left these countries.

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SMOKE ACID PRODUCTION

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

EXHIBIT C-1

CAPACITIES IN POWDER AND EXPLOSIVES INDUSTRIES

Capacities Actually Reached

Figures extrapolated from actual production figures and planning figures.

Metric tons per month

	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
Powders	1,000	2,000	3,000	4,000	5,000	6,500	9,000	11,000	15,000	18,000	25,000	28,000
Explosives	2,000	3,000	4,000	4,500	5,500	8,000	12,000	16,000	20,000	24,000	27,000	34,000
Extenders	4,000	4,000	4,000	5,000	8,000	12,000	15,000	17,000	22,000	30,000	35,000	43,000
Nitric acid Hoko	10,000	12,000	14,000	16,000	20,000	26,000	33,000	35,000	46,000	54,000	65,000	70,000

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POWDER PRODUCTION AT DUNEBERG FOR ROCKET MUNITIONS IN 1944

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

EXHIBIT RA

POWDER PRODUCTION AT DUNEBERG FOR ROCKET MUNITIONS IN 1944

	Powder Delivered									
	1st Quarter		2nd Quarter		3rd Quarter		4th Quarter		Year 1944	
	Tons	Charges	Tons	Charges	Tons	Charges	Tons	Charges	Tons	Charges
For 15 cm NC.w.41 1 charge = 5.9 kg	432	73,300	433	73,500	500	84,800	405	68,000	1,770	300,300
For 23/32 cm NC.W.41 1 charge = 6.5 kg	273	42,000	260	40,000	299	46,000	171	26,300	1,003	154,300
For 30 cm NC. 42 1 charge = 15.1 kg	529	35,100	546	35,200	603	40,000	528	35,000	2,206	146,300
For 15 cm R'G'v. 19 1 charge = 5.1 kg	10	1,960	-	-	-	-	-	-	10	1,960
For 28 cm R'G'v (K5) 1 charge = 19.6 kg	2	110	-	-	-	-	4	220	6	330

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GERMAN POWDER PRODUCTION FOR ROCKET MUNITIONS 1944

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

EXHIBIT RB

GERMAN POWDER PRODUCTION FOR ROCKET MUNITIONS - 1944

PLANNED PRODUCTION OF 19 FEB 1944

		Numbers of Charges				
		Jan	Feb	Mar	Apr	May
15 cm NC.w.41 (5.9 kg P)	Bomlitz	80,000	90,000	90,000	80,000	80,000
	Duneberg	25,000	25,000	25,000	25,000	25,000
	Bramberg	10,000	10,000	10,000	25,000	30,000
	Klick	10,000	10,000	10,000	10,000	10,000
	Oderberg	20,000	20,000	20,000	25,000	25,000
	Torgelow	--	5,000	5,000	10,000	15,000
28/32 cm NC.W.41 (6.5 kg P)	Duneberg	12,000	12,000	12,000	8,000	8,000
	Reinsdorf	--	--	4,000	4,000	4,000
21 cm NC.W.42 (18 kg P)	Bomlitz	18,000	18,000	18,000	18,000	18,000
	Bramberg	15,000	12,000	10,000	10,000	10,000
	Oderberg	5,000	5,000	5,000	5,000	5,000
30 cm NC.W.42 (15.1 kg P)	Duneberg	5,000	5,000	10,000	10,000	10,000
	Bramberg	3,000	3,000	5,000	8,000	8,000

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LOCATION OF POINTS PRODUCING SPECIAL PROPELLANTS, TABLE AND MAP

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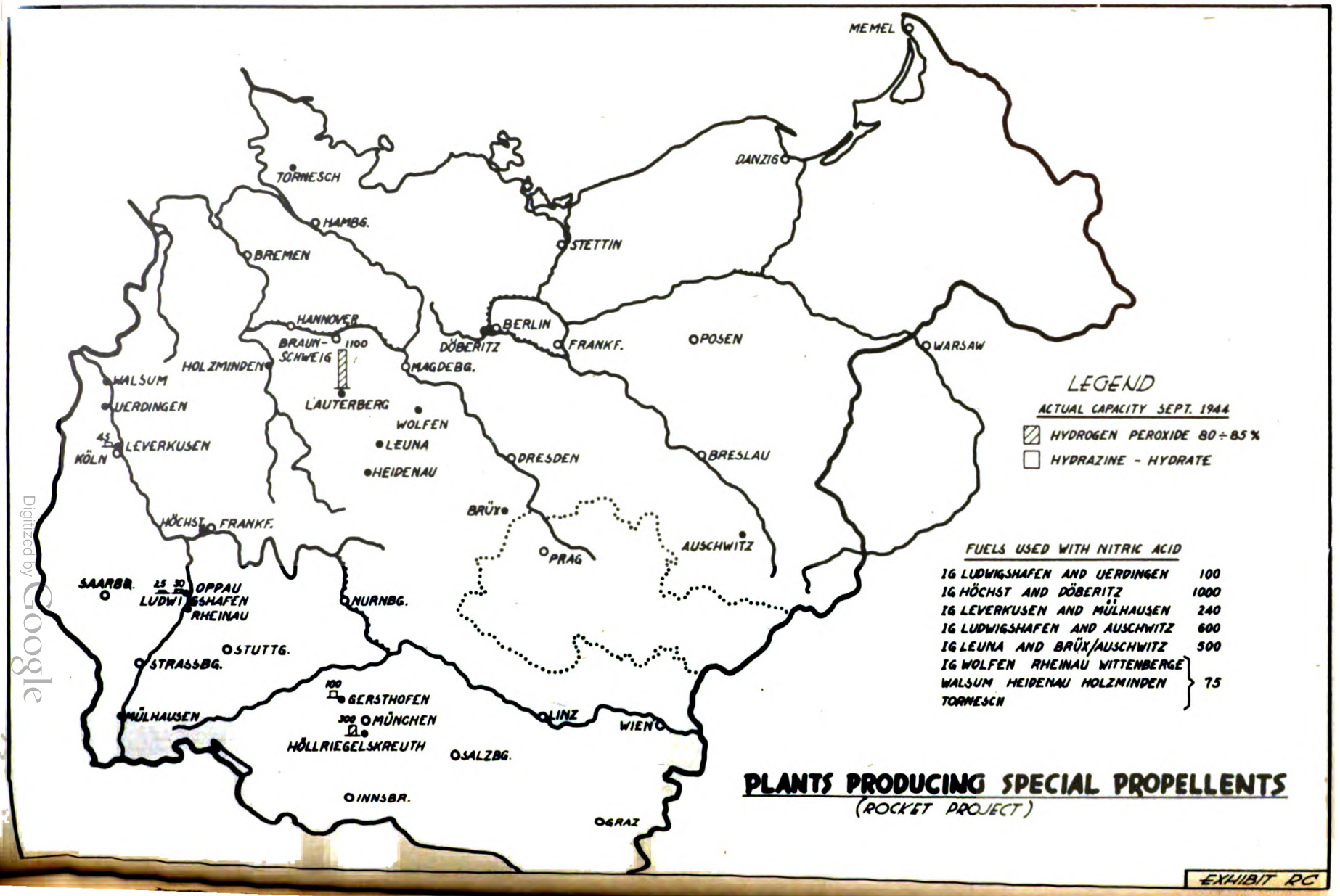

PLANTS PRODUCING SPECIAL PROPELLENTS

(ROCKET PROJECT)

EXHIBIT RC

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EXHIBIT BC

Plants for Production of Special Propellants (Rocket-projects)

Products, locations and firms		Start of production	Capacity Sep 944) tons per month reached	planned x)
1.) Hydrogen-peroxide (85%)				
Munich-Hollriegelskreuth	Elektrochem.werke, Munich	before war	300	500
Lauterberg-Harz Mountains	Schickert a.co.	1942/43 xx)	1.100	1.150
Rhumspring-Harz Mountains	" "		-	2.100
Oppau-Ludwigshafen (Rhine) (Permalin)	IG Farbenindustrie AG	1943 xx)	30	30
Heydebreck (Upper-Silesia) (Renal)	" "		-	2.000
Waldenburg (Upper-Silesia) (Ceprol)	" "		-	2.000
		Total:	1.430	7.780
2.) Hydrazine Hydrate				
Ludwigshafen (Rhine)	IG Farbenindustrie AG	few motos before war for civilian purposes, more since Sep 1944	25	25
Leverkusen (Cologne)	" "		45	60
Gersthofen (Augsburg) includ. dislocations	v.Transche a.co.		100	300
		Total:	170	385
3.) Z-catalyst (containing permanganate)				
Munich-Hollriegelskreuth	Elektrochem.Werke, Munich	effective production unknown, but always sufficient		
4.) "Hypergoles" (=self-inflammables by nitric acid):				
methyle-or ethyle-amines	IG Ludwigshafen and Uerdingen)	before war	100	ca.200
anilines	IG Hoechst and Doberitz	for civi-	1.000	"1.300
xylidines	IG Leverkusen and Muhlheusen.)	lian purposes	240	240
vinyl ethers	IG Ludwigshafen and Auschwitz)		600	1.200
pyrocatechols	IG Leuna and Brux/ Auschwitz)	1943 and/or	500	1.000
furfuryl-alcohols	IG Wolfen (85), Rheinau (35),) Wittenberge (75), Walsum (65)) Heidenau (25), Holzminden (8)) Tomesch (7)	1944		
		Total:	2.515	4.240

x) means the final capacity planned in Sep 1944, mostly to be reached years later. xx) = estimated

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T-STOFF NORMAL

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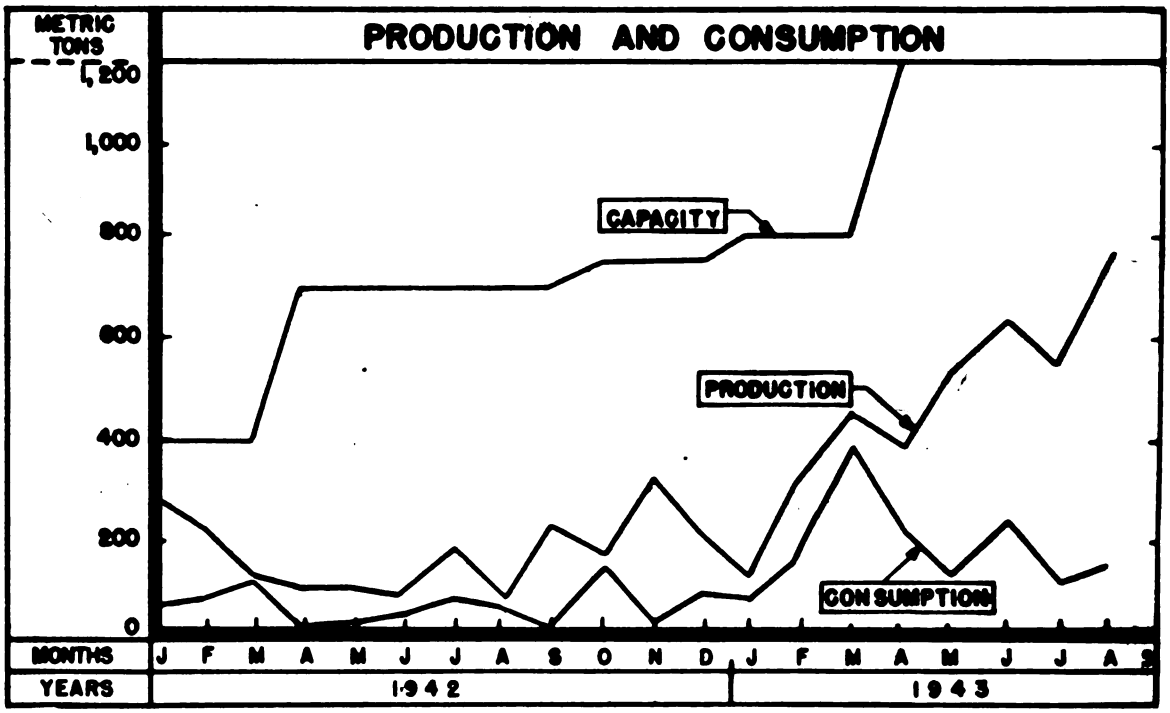
T- STOFF NORMAL

(85 % HYDROGEN PEROXIDE)



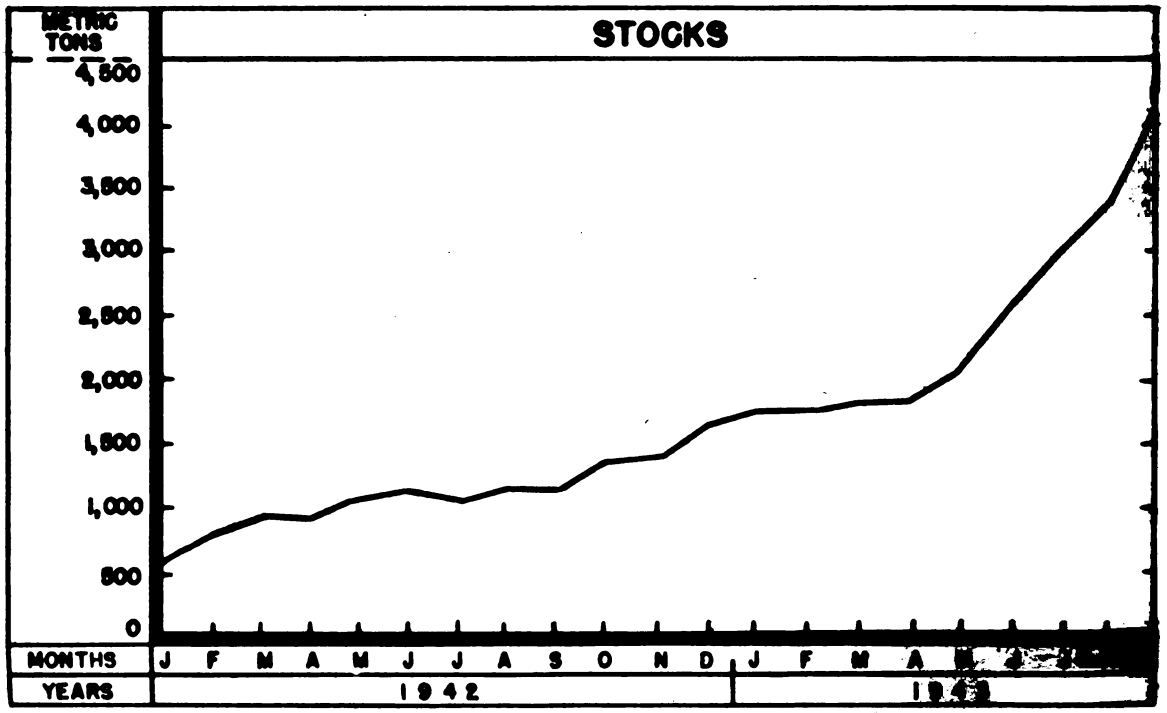


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EXHIBIT-RD

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T-STOFF SPECIAL

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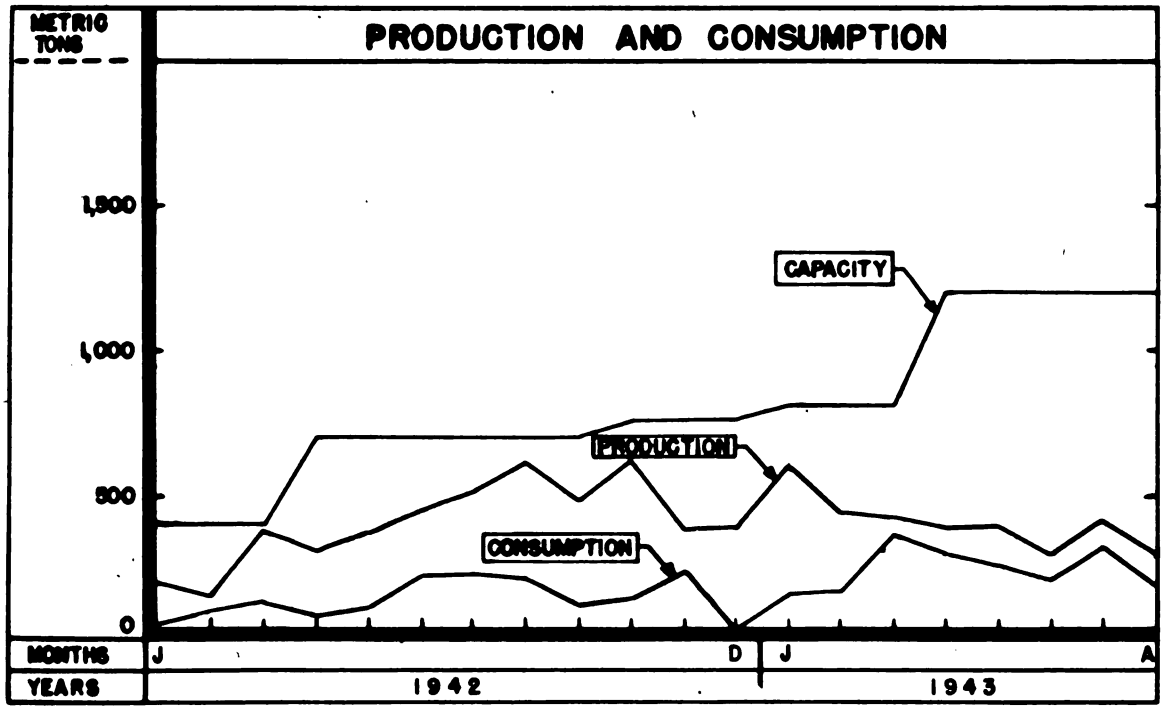
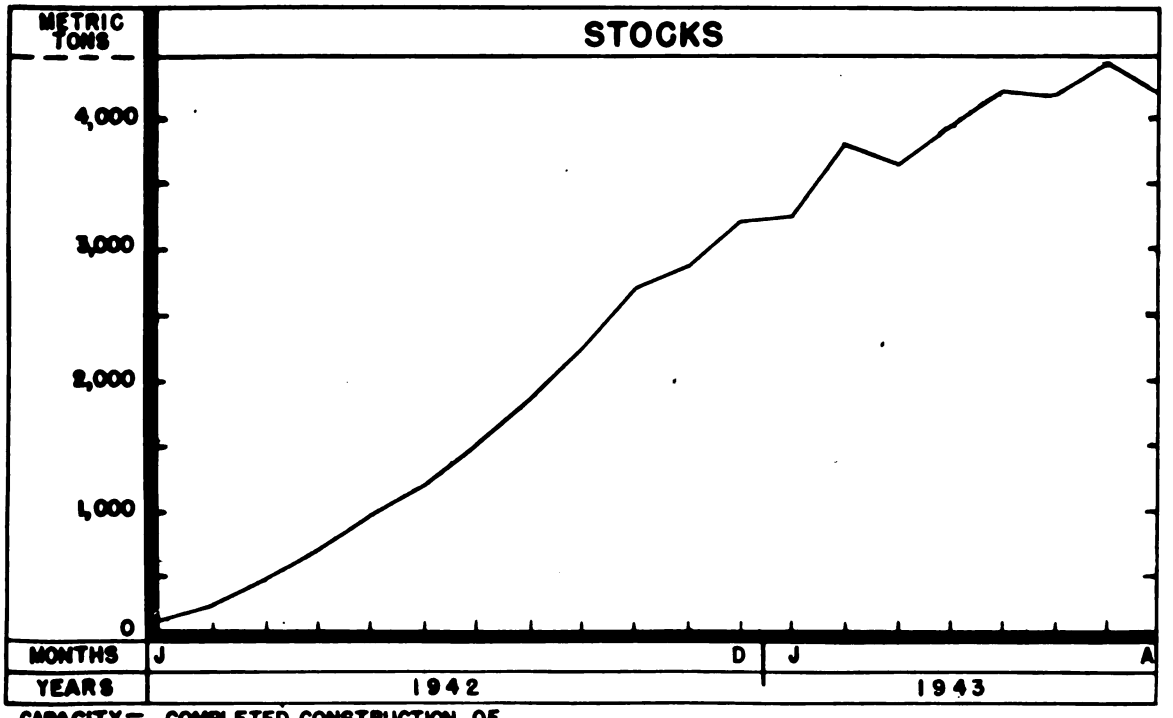
T- STOFF SPECIAL

(85 % HYDROGEN PEROXIDE)





CAPACITY— COMPLETED CONSTRUCTION OF THE EXPANSION PLAN FOR T-STOFF TOTAL (NORMAL AND SPECIAL)

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EXHIBIT RE

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DIAGRAM OF HYDROGEN PEROXIDE PRODUCTION

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DIAGRAM OF HYDROGEN PEROXIDE PRODUCTION BY ELECTROCHEMISCHE WERKE MÜNCHEN BY THE PERSULFATE PROCESS

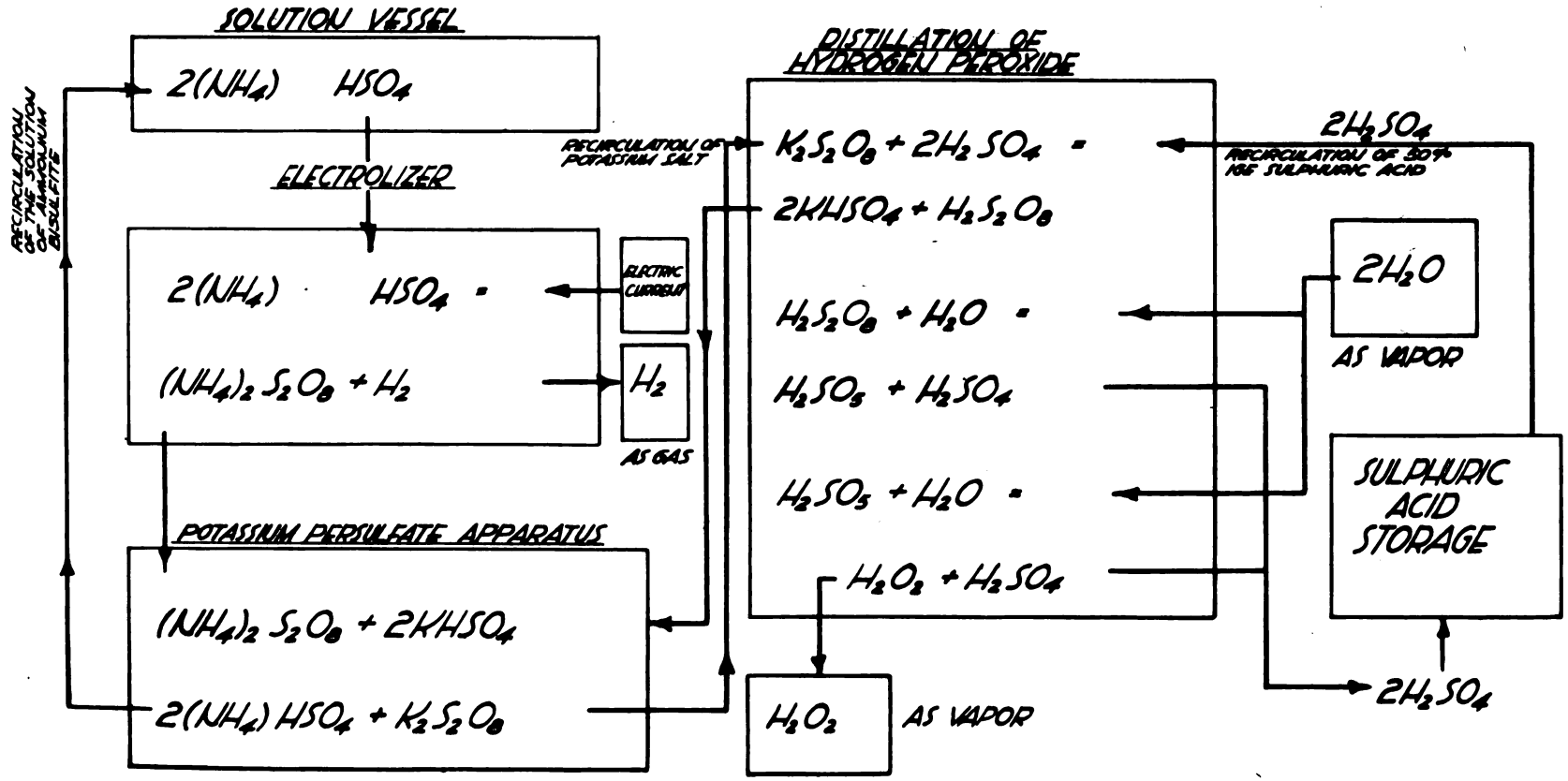

EXHIBIT R E

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FLOW SHEET PIETSCH-ADOLPH PROCESS

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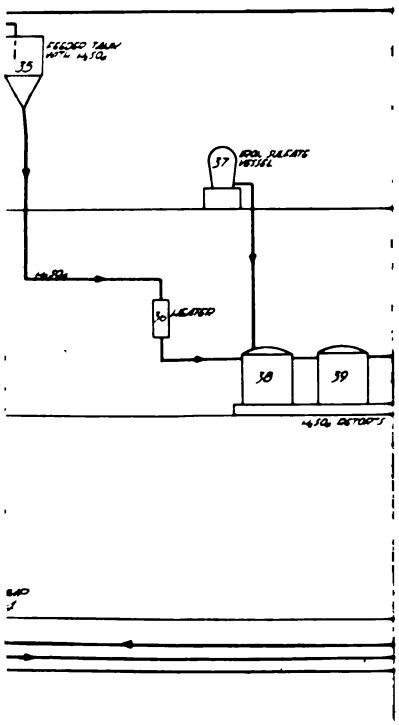

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FLOW DIAGRAM PERMANGANATE PROCESS

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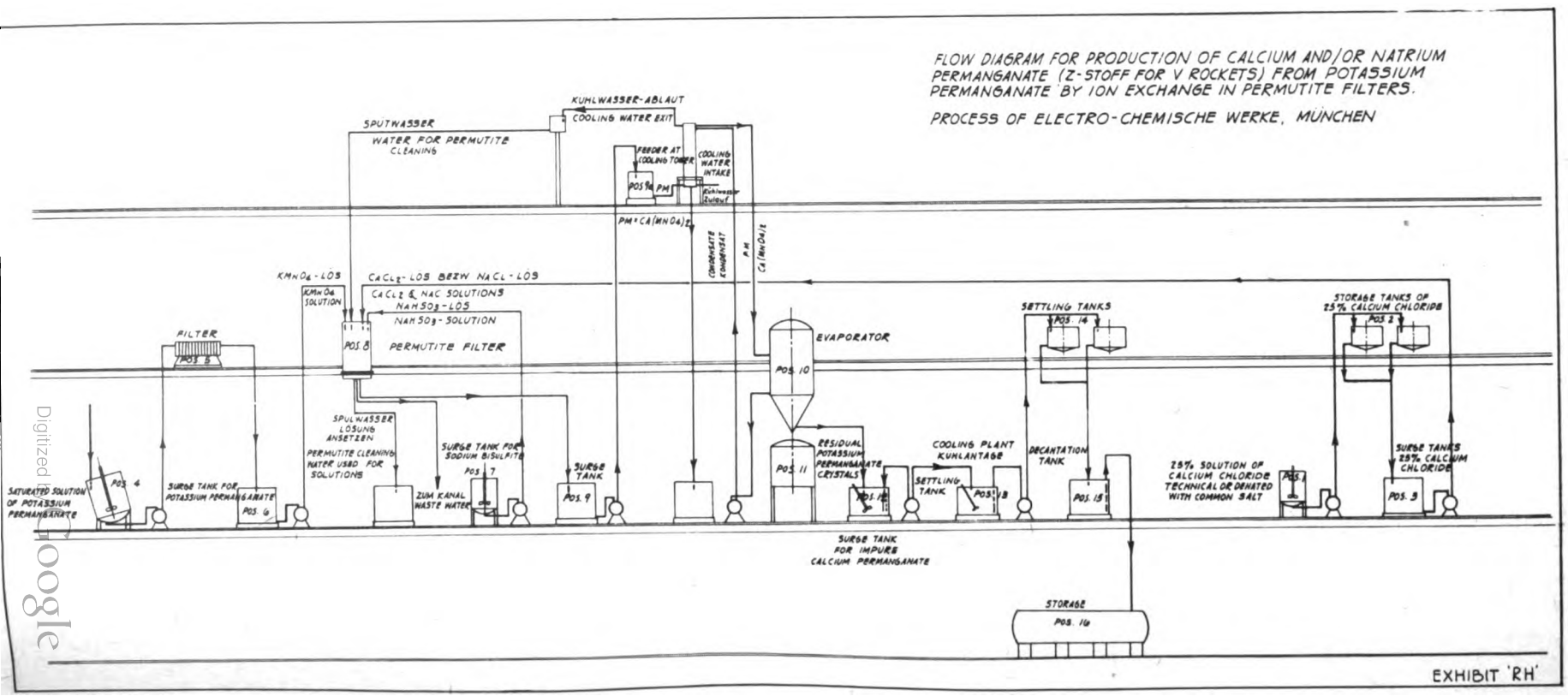

EXHIBIT 'RH'

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RAW MATERIALS FOR R PROGRAM

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

EXHIBIT RI

CHS/bl
Berlin, 29 June 1943

RAW MATERIALS FOR THE ROCKET PROGRAMS.

As a consequence of an inspection trip of the General Commissioner for Chemicals to Peenamunde and Kiel and after discussions with the special employees as well as the Office for Armament Supply the following information was obtained:

1) Defensive weapons.

1. The rocket propelled fighter is being developed very rapidly to a very fast rate of climb, and because of this, as well as its speed, will be superior to every bombing plane used in the near future in speed and rate of climb.

Planned operations: 1,000 fighters with 10 sorties each per month = 10,000 sorties. 500 fighters with T-stuff (hydrogen peroxide) propellant. 1) 500 fighters with rock acid propellant. 2)

Raw material needs.

a) With T-stuff propellant

5,000	tons	T-stuff
600	"	Methanol
800	"	Bertolin
6,500	"	Hoko acid
1,600	"	fuel (the choice depending on products available in the chemical industry is not yet finished)

2) The Armament of the Fighter.

The fighter, which is not in a position to defend itself successfuly against the closed defensive formations of bombing planes with the present armament will be given the requisite superiority by rocket launchers or the free-recoil canon (similar to the air-landed gun). For both weapons powder will first of all be used as a self-starter. The fighter will be catapulted as a means of starting. For the drive of the catapult sled T-stuff is suggested as propellant (formerly development was in the direction of powder-driven mechanism).

Rawmaterial needs:

The necessary quantities of powder and explosives can be fitted in with the whole Powder and Explosives-Program. Assume : .12 tons powder and .2 tons explosives per sorty.
For catapult drive (estimated) 120 kg T-stoff per start
about 1,200 tons T-stoff.

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EXHIBIT RI

1) T-stoff to produce oxygen for the oxydation of Methanol and Bertolin fuel.
2) Hoko acid to produce oxygen for the oxydation of several organic compounds, among them (approximately 30 per cent Amine and Visole fuels).
3) The anti-aircraft rocket C-2 Waterfall.

Based on the large fluid-driven rocket A-4, a shell is being developed which can shoot 80 - 100 kg of explosives much higher than the range of anti-aircraft (up to 15 km altitude). The fundamental difference from the small anti-aircraft shell is not only the multiplied explosive content and the higher effective altitude, but above all the absolute accuracy of fire. This is obtained by the fact that the shell aims towards the target by radio direction, even through cloud cover and, as a consequence must automatically follow its target. Because of its range of up to 45 km, it is possible now that the hostile bombers can be reached before dropping their bombs. In this development there is, for the ground defense, an absolutely decisive superiority over everything which was in use before. The development up to to-day - especially for high ranges and altitudes - foresees fluid drive (Hoko nitric acid and fuel). Rockets with powder drive are also being developed - for the present, however, only up to 6 km altitude. By means of new results of Dynamit AG with continuous powder processing with snail presses there is a way for mass production of rocket propelling sets. At the same time the development of yellow powder (Giessbare Pulver) lies in this direction. Higher altitudes can be foreseen with powder drive.

Planned expenditure: 10,000 C-2 units per month 3) (previous claim 5,000)
Raw material needs: 16,000 tons Hoko acid per month
4,000 tons of fuel of which 2,800 tons Visole (the choice of other products on hand in the chemical industry is not yet finished)
1,000 tons explosives per month.

II. Attack weapons

(excluding the powder-rockets (rocket morter) or R-grenades for the Army.)

I) The long distance-rocket A-4 shoots for ranges of about 300 km with an explosive load of 1 - 1.7 tons. This development, which had depended on the control of the oxydation process for the rocket drive, and above all, the automatic radio-technical direction of the whole shell, can mainly be regarded as finished. The shell developed from this rocket represents a highly complicated and expensive mechanism - especially the electrical part - and can therefore be used only to a restricted extent for the defense of special war essential targets. The steering is by means of a radio beam, and at 300 km the dispersion is about 1,000 m.

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3) Hoko acid as oxygen support for the oxydation. Visole as self-fuzed fuel mixed with different organic compounds. If efficient anti-aircraft rockets can be developed with powder drive, then the most essential part of these powder needs must be taken from the present aircraft program, since a further increase in thepowder program offers great raw material difficulties.

Planned expenditures:	900 A-4 units per month 4)	
Raw material needs.	13,000	tons liquid oxygen per month
	4,000	" alcohol, 95% (actually 75%)
	2,000	" Methanol
	500	" T-stuff (peroxide)
	1,500	" explosives

Up to now an important part of the alcohol and oxygen was used for testing the apparatus before shooting. Later on with further devel opment of large scale production a decrease of raw material can be counted on. That is to say, with the same quantity of raw material more apparatus can be made available.

2) "Cherry-stone" FI 103

In contrast with A-4 "mass projectile" for long ranges, is a pilotless small plane equipped with a simple gasoling pulsation drive (Argus). The plane is started by a catapult which is supplied with hydrogen peroxide or a powder drive. The speed is nearly that of a fast bomber. The accuracy of fire is not great. Therefore it is adopted only for massed attacks on large areas. The explosive filling amounts to 1.5 tons.

Planned expenditures:	3,000 Fi 103 units monthly	
	300	tons hydrogen peroxide for catapults (100 kg per start including reserves)
	2,100	tons aviation gasoline (normal quality)
	4,500	tons explosives

4) Liquid oxygen for the oxydation of alcohol with an admixture of Methanol as fuel. Hydrogen peroxide as propellant of the auxiliary machines in the shell.

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EXHIBIT RI

Summary

Most important raw material requirements of the Armaments-Program in tons

(on 30 June 1943)

Fighter	oxygen-carrier hydrogen peroxide	Hoko-saure	liquid oxygen	fuel	powder	explosives
Apparatus and	5,000	6,500	-	800 Methanol 800 Bertolin 1,600 organic compounds with 30% of Amines and Visole		
R-board weapons	-	-	-	-	about 2,000	2,000
Catapult	1,200	-	-	-	-	-
C-2 "Waterfall"	-	16,000	-	2,800 Visole 1,200 organic compounds	-	1,000
Fi 1-3 "Cherry-stone" Apparatus and drive	-	-	-	2,100 aviation gasoline	-	4,500
Catapult	300	-	-	-	-	-
A-4	500	-	13,000	4,000 alcohol 95% 2,000 Methanol	-	1,500
Total:	7,000	22,500	13,000	4,000 alcohol 2,806 Methanol 2,100 aviation gasoline 800 Bertolin (hydrozinehydrate) 3,000 Visole 2,600 other organic compounds	about 2,000	ab. 9,000

without the other powder and explosive requirements of the Army for mortars or R-grenades

without the needs of hydrogen peroxide (about 2,860 tons) for the Navy-Program.

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EXHIBIT RI

Possibility of covering the requirements:

Hydrogen peroxide: The need of about 10,000 tons, including naval requirements cannot yet be met by the program (6,800 tons) which is about to be carried out. The erection of further installations must immediately be decided upon or the development of the fighter-drive must be much more dependent upon Hokosaure for which also a further extension will be necessary.

Hokosaure: In the Powder Explosives Program it was foreseen that 15,000 tons would be required for the R-drives. To cover the full requirements corresponding changes would have to be made with regard to powder and explosives, or the production of Hokosaure would have to be increased systematically if such interference seems to be impractical.

Liquid Oxygen: By the erection of oxygen installations and the taking of liquid oxygen out of the Linde-installations of the large hydrogenation works and nitrogen works the required quantity will be secured. This extension has already reached the DE-grade.

Fuel: Alcohol, Methanol, aviation gasoline and the other required organic compounds can be taken from the available quantities or from the programs now in process of execution at the expense of other consumers, without great difficulties.

For Bartolin an increase is being affected up to 500 tons, and an expansion must be provided. Visoles can be created with 800 tons in Ludwigshafen with small investment. The remaining quantities of about 2,200 tons must be produced, for instance in Auschwitz. The development to replace Visoles by other available organic compounds must be speeded up.

Powder and Explosives: The necessary quantities must be taken out of the PS-Program (Powder and Explosives Program) by shifting requirements.

Conclusions:

An exact time schedule for equipment and the covering of raw material requirements must be made speedily.

Today it can be said that the extension of hydrogen peroxide, Visolen, and Bartolin must be put on a DE-basis, in order to produce roughly on time. With the other products time difficulties can be balanced at the expense of other consumers.

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EXHIBIT RI

Remarks on the Armaments Program

Notes on a discussion with State Councillor Dr. Schisber after a visit to Peenemunde and Kiel.

The general opinion is that the development of the rocket as a decisive weapon is now vital. Regarding the present effects of the enemy air war on us the question arises, whether we are on the right way in pushing forward the development of the offensive rocket. The air war against our population centers at present is the only effective war weapon of the enemy. Its psychological and material effects will increase, for the present means of air defense are evidently insufficient. The representatives of the rapid development of the offensive air weapons--that is, the counter terror, are of the opinion that attack is the most effective defense and that our counter action with the rocket must lead to a decrease of the air attacks from England against the Reich. But even assuming that the long-range rocket can be used to an unlimited extent and really causes large-scale destruction, this conclusion seems to be false according to experiences up to today. On the contrary, the present adversaries in England of the air terror against the German population, after our rocket attacks which destroy their cities without costing us any victims or risks, will consider the British terror, which requires some personnel bravery, as the form of war which is less unfair, and therefore will demand from their Government an increase of air terror against our population centers which will be nearly unprotected. But above all the enemy Air Force will of course immediately attack the places of production for this new means of air attack, for the protection of which no suitable means will be available. By this the offensive use of this new means will be made impossible. This must therefore remain wishful thinking until the air defense has been fundamentally changed. If on the other side first our air defense will be effectively corrected by the development of air rockets two things will be obtained at the same time:

1) The counter-air terror (without risk) will be protected against enemy air efforts. Its effect on morale will increase the more, the less the enemy can retaliate. By this our own air terror will perhaps have decisive influence on the war because, although as a consequence of our operations the enemy will immediately develop his own rocket weapon, he cannot reach the Reich from England nor Italy from Africa. These considerations favour a further concentrated pushing forward of the whole rocket development, especially, however, of the air defensive weapon, the C-2 "Wasserfall" apparatus. Their employment must be effected in greatest numbers and with full striking power and the effect must be so paralyzing and destructive that even concentrated attacks on the factories of the rocket weapon (which have to be created in the East and be highly dispersed) cannot substantially hinder the operation of these means of war. The aim of operating with this rocket weapon is obtained, if the enemy, owing to our superior air defense abandons the air terror against our population and armaments centers and is forced to attack by land where we have a sure

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superiority. By means of this, our confidence of victory will be raised and our armament potential will at the same time be maintained. Besides, the dispersal of industry which costs much effort and time will be avoided as well as the evacuation of the population with all its consequences.

In other words: Each expert, each worker and each hour of work, used in order to push forward this program to the utmost, produces a multiple result regarding the decision of the war, greater than any other program would do. Any delay of this program can have decisive results.

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EXHIBIT RI

Enclosure to Daybook No 111 K

Berlin, 29 June 1943

Suggestion to the organization development of the R-Program

(notes on a conference with State Counciller Schieber)

The decisive importance of the R-apparatus, especially of the anti-aircraft rocket C-2 requires a strict and unified direction of the total Armaments-Program as to

(1) fixing of objectives
(2) development
(3) industrial production of the apparatus
(4) supply of raw materials and fuel:

with the aim of obtaining in a short time a mass output, especially for C-2.

For this purpose it is suggested:

A special commissioner under the Reichs Minister for Armaments and Ammunition and the Reichs Minister for Aircraft is charged with the execution of the R-Program. He has extraordinary authorities and is free of all other tasks.

The Program (or special parts of the program) receive the higest priority (DE).

This special commissioner is Major General Dornberger and a man from the Air Force, still to be appointed, will be responsible for:

a) the total development and exchange of experiences
b) the output of apparatus according to time schedule (especially radar) the Armament Supply Office for propellants and other chem ical raw material questions.
c) Delegate Gen (Chemistry) who depends on co-operations with the SKN raw material department.

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JET PROPULSION EQUIPMENT

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

EXHIBIT RJ

Installations for Manufacture and Storage of Rocket Propellants Situation as of 10 January 1945

Installation	Manufacturing	Percentage of total German capacity
In operation		
1. Bad Lauterbg Schickert & Co	T-stoff	53
2. Rhumspringe Schickert & Co	T-stoff	33
3. Höllriegelskr Elektrochem Werke Munchen A.G.	T-stoff Z-stoff	14 100
In construction		
4. Heydebreck I.G.Farbenindustrie Anlauf 1.5.45	Renal (T-stoff)	16
5. Waldenburg I.G.Farbenindustrie Anlauf 1.6.45	Geprol (T-stoff)	16
In operation		
6. Gersthofen Chem. Fabrik Gersthofen v.Transehe & Co	B-stoff	70
7. Leverkusen I.G.Farbenindustrie	B-stoff	20
8. Ludwigshafen I.G.Farbenindustrie	B-stoff	20
Special storage facilities		
9. Neustadt a d Dosse Werk Dreetz Dtsch.Sprengchemie		3

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EXHIBIT RJ

Installations for Manufacture and Storage of Rocket Propellants Situation as of 10 January 1945

Installation	Manufacturing	Percentage of total German capacity
10. Forst i d Lausitz Werk Forst Dtsch Sprengchemie		3
11. Torgelow/Pom Dtsch Sprengchemie		6
12. Oderberg/Mark Dtsch Sprengche mie		10
13. Kraiburg/Odbg Krs.Mühldorf Dtsch Sprengchemie		10
14. Hitzacker/Elbe Wirtschaftl Forschgges		16
15. Geesthacht (Bez. Hambrg) Werk Duneberg Dynamit AG		13
16. Krummnussbaum b/Wien Wifo		13
17. Barey b/Burg		13
18. Ebrach b/Bamberg Wifo		13

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

EXHIBIT RL

Armament Delivery Office
Office Group Powder-Explosives
RIA PSV/PS III 151-668/44 g Re.

SECRET GOVERNMENT MATTER

Berlin, 19 June 1944
188 Potsdamer Street
11 00 52/1133 - Dr. Schultz

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JET PROPULSION EQUIPMENT

Order No.	Equipment	Location of Development	Propellant	Remarks
1	Jet-propelled fighter Me 163 B	Walter Messerschmidt	T-Stoff (80-85% H_2O_2) /B-Stoff (hydrazine hydrate)	Engine in series production; difficulties are still being encountered in connection with the cell: training has started on several air fields.
2	Jet-propelled fighter Me 163 C	1) BMW (Bayerische Motoren Werke) 2) Walter	Hoko (98% nitric acid) / Amines	Engine is still in state of development; will be in action probably by the end of 1945
3	TL-fighter Me 262	Walter	T-Stoff / B-Stoff	Auxiliary engine supplementing the jet-engine to improve climbing performance is in the state of development. - It has not as yet been decided whether the Walter or the BMW (Bayerische Motoren Werke) development will be used. (Walter has an independent drive for the feed pumps; BMW couples the feed pumps with the engine).
4	TL-fighter Me 262	BMW	Hoko / Amines	

Requirements per start: 1.6 tons of T-Stoff / 0.5 tons of B-Stoff-methanol mixture (30/70) (0.15 tons of B-Stoff).
Speed: 900 Km./hr.
Driving force: 1.5 tons

Combat range: 70 Km.) Wing span: 9m.
Flying range proper, including gliding: 300 Km.) Length: 6m.

Climbing speed: 1,000 m. in 2 minutes, ceiling in about 3 minutes.
1) With level flight combustion chamber: 10,000m in 2 minutes, ceiling in 9 minutes

1.) According to information received from the fighter staff, 500 fighters are planned for 1944, of which presumably 25 per cent (125 fighters) may go into action at any one time. The number of possible starts per month is not clear. Requirements including test block and acceptance tests are estimated at 12,000 tons per month in the last quarter of 1944 and 1,900 tons per month in the second quarter of 1945. A maximum of 600 sorties per month is expected, corresponding to about 1,000 tons of T-Stoff.

Climbing speed: 150m./sec. Conventional fighter; 2000 HP, 21m./sec.
Driving force: 1.8 tons = 7500 HP

Me 263 (248)

Climbing combustion chamber: 2 tons driving force
Level flight " " : 0.4 tons driving force

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

Order No	Equipment	Location of Development	Propellant	Remarks	
5	Fi (Fieseler ?) 103 (FZG 76)	Argus (Engineer Schols } 120047 2880 (Engineer Kensel } 2544	Gasoline (B 1)	Equipment in series production. Propulsion through Argus tube.	Explosive: 850 kg. Amatol 39 A: limit of accuracy 10x10 km. Gasoline: 670 liters B1 Range: 255 km. Speed: 600 km./hr.
6	Launching device for Fi 103	Walter	T-Stoff / Z-Stoff (calcium permanganate)	Equipment in series production	T-STOFF: 85 kg.at head-wind:115 kg. at tail-wind; / 100 kg. Z-STOFF: 6.5 kg.
7	Auxiliary launching device	Walter	T-Stoff / Z-Stoff	Equipment is in use, however, it seems that it is being substituted by a launching device on power basis	
8	Air torpedo LT II A 1	Walter	T-Stoff / B-Stoff	In the state of development	
9	Glider bomb HS 293 A HS 293 C HS 294 HS 296	Walter	T-Stoff / Z-Stoff	Some units are already in use	
10	X 4 (equipment 78)	HHM RLM (Reich Air Ministry) /CS 3 (Dr. Boek) Series Production	Hoko and Tonka 250 (triethylamine / xylidine)	Board weapons: being tested. V-Series of 225 units. O-Series of 1000 units has been started	Explosive: 25 kg. } 88 plans thereof Hoko: 6.7 kg. } X4 for anti-tank Tonka: 1.8 kg. } purposes. The Flying time: 80 sec. } number of units "Reichweite" (maximum range ?): 3-4 km.) planned is at "Schuss" (effective range ?): 2 km.) present 3000. The steering is probably a bottle-neck.
11	Naval torpedo	Walter	T-Stoff / B-Stoff / Hydrocarbons	Series production has started; will go into action at the middle of 1944	T-Stoff: 140 kg.; test block, including acceptance tests: 200 kg. T-Stoff Decaline: 17 kg. Trial fire: 3 rounds Explosive: 300 kg. S 18
12	U-Boat	Walter	T-Stoff / Z-Stoff	In the state of development; 4 experimental boats being tested	At present 4 boats are available having a requirement of 80 tons per mission. By the end of 1944, 5 additional boats will go into service, having a requirement of 100 tons per mission each. For training, one charge per boat per month is required. Total requirement: 4 charges per boat per year (1/3 charge per boat per month).
10 a	HS 296	Schmidding	Powder (pressed or cast)	Board weapon:	Explosive: 25 kg.

Walter U-Boat:

Turbine: 14,000 R.P.M.
Decomposer: 350°C.,30 atm. gauge
Combustion chamber;550°C,30 atm. gauge, cooling by injection of H2O
Electric ignition during start

Speed under water:
7.4 knots old boat
17 " E-U Boat 5000 HP, for 1 hour (22.5 sea miles)
24 " Walter Boat 7500 HP, for 6 hours ("180 S.m." crossed out in the German text)

E-Boat: 1630 tons, 6 tubes, 20 torpedoes
W-Boat (type 26): 772 tons, 10 tubes, 20 torpedoes
Type 21 (E-Boat):30 kg./HP, 56 liters/HP, 1.2 hr.,22.5 sea miles
Type 16 (W-Boat): 12 kg./HP, 28 liters/HP, 7 hr., 180 sea miles (13,000 HP)

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Order No	Equipment	Location of Development	Propellant	Remarks	
13	A 4	H A P 11 (Dornberger)	Liquid oxygen + alcohols T-Stoff + Z-Stoff	Equipment is series production	1st. Test block run. Explosive: 800-100 Kg., FP. (TNT/ammonium nitrate) 60/40 Liquid oxygen: 5.5 tons Mixture: 4 tons (30% methanol, 45% ethanol, 25% water) T-Stoff: 165 Kg. Z-Stoff: 12.5 Kg.
14	Wasserfall	G 1-Flak E (Halder)	Mixed acid (nitric + sulfuric acid) + Visol propellant	In the state of development: supersonic speed	Explosive: 250-300 kg.: driving force: 8 tons Hoko: 1610 kg. (1022 liters filling space) Fuel: 375 kg. (411 liters filling space) No test block run.
15	Enzain	Walter	Mixed acid + vinyl acetate-propellant or Visol propellant	In the state of development: subsonic speed	500 kg. explosive
16	Rheintochter I	G 1-Flak E with Borwig	Powder	In the state of development: subsonic speed; several units have already been fired	
17	Rheintochter III	G 1-Flak E	1.) Powder 2.) Mixed acid + Visol propellant	In the state of development: subsonic speed; the equipment will be so constructed that it may be operated either with powder or liquid propulsion	100-150 (kg. explosive ?)
18	Schmetterling (8 - 117)	G 1-Flak E with BMW	Hoko + Amines	Development of the propulsion device is completed; development of the cell started by Henschel. Series production will start probably at the end of 1944	Hoko:Tonka 505o = 4.65:1 Hoko: 59.2 Kg; flying time: up to 2 minutes Propellant: 12.7 kg. Explosive:

No 1 - 10 units of the Air Force
" 11 - 12 " " " Navy
" 13 " " " Army
" 14 - 18 anti-aircraft rockets

Directing beam control up to 60 km. altitude, culmination point at 90 km. altitude; speed: supersonic speed.

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

EXHIBIT RK

Raw Materials Office
Office Group Chemistry
PS III No. 1529/44 gRs

Berlin, 15 January 1945

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NOTE FOR DR KOLB

Re: Rocket Propulsion using 98 per cent Nitric Acid

The High Command of the Air Force requests by letters of 2 January 1945 (20043/45 gK) and 7 January 1945 (60503/45 gK) a basic decision as to whether 98 per cent nitric acid may be made available for rocket propulsion.

The Air Force had started to develop rocket propulsion on the basis of 98 per cent nitric acid at the beginning of the war because it was clear from the beginning that "T-stoff" (80-85 per cent hydrogen peroxide) would not be available in amounts sufficient for the Air Force and the Navy.

Equipment coming into large scale production is as follows:

1). Equipment 8 - 344 (X4)

X4 will be used as a weapon to fight aircraft; the equipment will operate on 98 per cent nitric acid and Tonka 250 (triethylamine: xylidine = 1:1). The requirements per unit are as follows:

98% nitric acid	6.7 kg
Tonka 250	1.8 kg
Explosive (Nipolit)	20 kg

In 1945 some 19,850 units will be built, having a total demand as follows:

Nipolit	400 tons	
98% nitric acid	140 tons	
Tonka 250	40 tons	(*)

(*) Will be made available from stocks.

2). Equipment 8 - 117 (Butterfly)

The "Butterfly" will be used from the ground as an anti-aircraft rocket against airplanes. The equipment will operate on 98 per

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cent nitric acid and Tonka 505c.

Tonka 505c		Demand 1945
Anilin	5%	28 tons
Ethylanilin	7%	39 "
Xylidine	12%	66 "
Xylene	15%	82 "
Optol	18%	99 "
Ethylether	25%	137 "
Gasoline	18%	99 "
	100%	550 tons

The total demand for 1945 will be:

Tonka 505c	550 tons
98% nitric acid	2560 tons

In addition, about 90 tons of 98 per cent nitric acid are needed for the production of the amines.

3). Equipment 718 (R-Propellant Unit (Rocket Propellant unit)

The Rocket Propellant Unit will be installed in the Me-262 (TL Fighter) to improve the climbing speed. The effective range is increased by the rocket propellant unit because less gasoline is consumed in climbing.

The High Command of the Air Force estimates the demand for 1945

Tonka 505c	2800 tons
98% nitric acid	10000 tons

About 500 tons have to be added for the production of the amines.

Aside from the above-mentioned equipment, other equipment being developed is as follows:

1). Me-143 C (Messerschmidt)

This rocket fighter was developed as a substitute for the Me-143 B for such time as the Navy will consume the major part of the T-stoff.

2). Enzian

Enzian is a large anti-aircraft rocket having an explosive charge of about 500 kg. It is contemplated that 500 units be built in

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1945, having a requirement of about 250 tons of 98 per cent nitric acid.

I request your decision as to whether, in view of the present nitrogen situation, 98 per cent nitric acid may be made available for rocket propulsion.

My suggestions as to details are as follows:

1). The demand for X4 and Butterfly should be made available.

2). With respect to the Rocket propellant unit for Me-262 of the Air Force, it should be proposed that a Walter propulsion be substituted on T-stoff basis. The T-stoff demand for this purpose would have to be supplied on the expense of the Me-143 B.

3). The decision on the feasibility of filling the demand for 98 per cent nitric acid for "Enzian" and Me-163 C should be postponed until the Plan figures are available.

(Signed) (Illegible)

1 Enclosure

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APPENDIX

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POWDER, EXPLOSIVES AND RELATED PRODUCTS

B - APPENDIX

1. Technical Discussion

For purposes of this report the German explosives and propellant industry will be classified in three principal categories as follows:

1. High explosives (used for filling shells and bombs to produce fragmentation or violent shock at the target).

2. Powders (for propulsion of shell or bullet to target).

3. Special propellants for rockets, V-weapons and jet propelled planes (these will be treated in Part II).

Initiators and primers, mainly mercury fulminate, lead azide, lead styphnate, lead dinitroresorcinate, lead mononitro resorcinate, and tetrazene will not be treated in detail because the quantities were very small (21 tons per month or .075 per cent of the explosives program in 1944) and, so far as can be determined, no shortages ever occurred. Unlike the situation existing in World War I, when practically the entire production of initiators and primers was concentrated in the one plant at Troisdorf, this manufacture was divided among eight plants: Schoenebeck, Reinsdorf, Wolfratshausen, Altberun, Empelde, Malchow, Walaschin and Brunn. Furthermore, although these initiating explosives are of critical importance, it was not possible to obtain production data in as much detail as in the case of the explosives produced in large quantities.

Both high explosives and powders exert their effect by a rapid chemical reaction which is essentially a combustion; the distinction between the two lying basically in the relative rates of that reaction. In high explosives it is so rapid as to constitute detonation; in powders it is relatively slow, progressive, and controllable in a confined space, such as a gun barrel, to exert its energy mainly on the projectiles. In general, both classes of materials incorporate two factors in their chemical composition, (a) an oxygen carrying factor and (b) a combustible factor. These factors may be embodied in the same chemical compound as in TNT and nitrocellulose, or as separate components of a mixture, such as black powder, which consists of saltpeter (oxygen carrier) and charcoal and sulfur (combustibles).

The principal German explosives powders and the raw materials from which they are made are shown in Table HX. It will be seen that almost all of these products are built up synthetically from ammonia, methanol, benzene, toluene and calcium carbide, the production of which, in turn, is based upon coal, of which Germany has an abundant supply. Wood, the source of the special crepe paper from which nitrocellulose is made, is also abundant in Germany. Glycerin from animal and vegetable fats and oils is not abundant in Germany, so that the amount of nitroglycerin pro-

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duced was not large (in recent years there were two synthetic glycerol plants). It was used mainly for double base nitrocellulose powders for naval use, but diglycol dinitrate was substituted for nitroglycerin to a large extent even in that application. (An additional raw material, strong sulfuric acid, is used to assist in the nitration). Several of the explosives listed in Table XV were used for special purposes and their volume of production was not large in the overall production picture; for example, tetryl for bursters, nitroguanidine for high altitude flak (8,000 - 12,000 m), PH salts for armor-piercing shells.

Ammonium nitrate and other weak explosives such as dinitrobenzene are used as extenders for pure high explosives such as TNT, Penta and Hexogen. As they contribute to the explosive effect, they are more than inert diluents, Ammonium nitrate production does not require the highly concentrated nitric acid.

Exhibit O, which is a translation of a similar chart prepared by the Planungsamt (Kehrl) presents an overall picture of the German powder and explosives industry. Lines I and II show the primary materials, solvents, and raw materials and their total average monthly consumption in metric tons planned for the first half of 1944. In a column below each chemical there is shown a breakdown of the percentage consumption by each of its principle applications. Applications to the powder and explosive industry are shown in the shaded area above the dividing line and all others below the line. It will be seen that the bulk of the production of the following chemicals in wartime Germany was consumed in powder and explosive manufacture.

Highly concentrated nitric acid (Hoko)	91.0%
Nitrocellulose	96.5%
Diglycol	99.6%
Toluol	87.7%
Pentaerythritol	83.0%
Calcium nitrate	80.0%
Calcium cyanamide	80.0%
Powder stabilizers	100.0%

Lines III show the various types of pure high explosives, with indications of the raw materials from which they are made, and the principal extenders for high explosives. Line IV shows the production of various forms of finished powders, propellants, filled munitions and ignition devices.

2. Methods of Manufacture.

The processes by which the principal explosives and propellants are manufactured are shown diagrammatically in the flow sheet of Exhibit R. Very briefly they are as follows:

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a. High Explosives

(1) Trinitrotoluene (TNT)

Toluene (or toluol) of special nitration grade, derived from coal tar distillates or synthesized from benzene and methanol is nitrated with a mixture of concentrated sulfuric and nitric acids in two or three process steps.

TNT was produced in Krummel by a three-stage nitration process in which the duration of nitration is eight hours for 3.5 tons.

Mononitrotoluene: (First stage of nitration)

Toluene is nitrated with the acid mixture containing 28 per cent HNO_3 and 56 per cent H_2SO_4 which is prepared from the weak spent acid from the second stage at a temperature of 35-40°C. The proportion of acids to toluene is usually about 2.5 to one. Nitrated product is left standing to separate the MNT from the acids; then it is neutralized and washed with water. The unreacted toluene and benzene are removed with steam in an alkaline medium. The wet product then goes to intermediate storage and is used for the second stage or nitration.

Di-Nitrotoluene: (Second stage of nitration)

Spent acid from the third stage of nitration reinforced with HNO_3 is used to produce DNT. The starting temperature of the reaction is 30°C. and is raised to 60° C during the course of the process and finished at 70-73°C. After the completion of nitration, di-nitrotoluene, the intermediate storage to be used in final nitration. Spent acid is used in the first stage of nitration, as described.

Tri-Nitrotoluene ($C_6H_2CH_3$) $(NO_2)_3$: (Third state of nitration)

The final product is obtained by reaction between di-nitrotoluene ($C_6H_3CH_3$) $(NO_2)_2$, and freshly prepared mixed acid containing 80 parts of oleum and 24 parts of 98 per cent HNO_3.

The proportion of acids to TNT is 2.6 to one.

Nitration is carried out at 74-78°C. The temperature of DNT introduced in the nitrator is 60°C. Reaction temperature is brought up slowly to 96°C. and is kept at this temperature until the end of reaction. After completion of the reaction, the insoluble TNT is separated from the acid. The acid is diluted with water to achieve complete separation and used in the second stage as described above. Raw TNT goes to the wash house for purification and removal of unsymmetrical unstable B and Y trinitrotoluenes.

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Washing of TNT

TNT, after separation, still containing some acid, is washed several times with 90°C water and neutralized with a solution of socium bicarbonate. Excess of bicarbonate is then removed with 85°C water. The unsymmetrical TNT's were removed with a sulphite wash at 76-78°C. Solidification point of TNT acceptable to the German army is 80.2-80.5°C. Excess of sulphite and all salts dissolved in it are removed by repeated washings with hot water. The wet product is piped to the drying house, where it is dryed in vacuum at 85°-90°C. Dryed product is cooled on steel drums and scraped from them in the flaked form and packed.

For production of TNT pressed bodies TNT is dissolved in alcohol and recrystallized.

Flow sheets for TNT manufacture are shown in Exhibits S T and U.

Almost all of the sulfuric acid and much of the unused nitric acid are recovered by a process of denitrating and reconcentrating waste acid from the various stages.

(2) Hexogen (RDX, Cyclotrimethylene-trinitramine)

Hexogen is one of the moden explosives of high brisance. The Germans developed several processes for the manufacture of Hexoger. These have been discussed in detail in Progress reports 24 and 43 by Captain Lee Nutting of ETOUSA, Office, Chief of Ordnance Officer, Research and Development Branch. The two used most generally were the SH process and the KA process. In the former, hexamine (hexamethylene tetramine made by reaction of ammonia and formaldehyde) is sulforated and the potassium salt is treated with a mixture consisting of 80 parts of nitric acid and 20 parts of sulphur trioxide. As a considerable amount of heat is evolved during this reaction, the vessel is cooled with water at the appropriate temperature. Hexogen is partially soluble in the acid, therefore, at the end of the reaction, the mass is diluted with water, and hexogen settled out. The mass is filtered on vacuum filters, the hexogen is washed with weak solution of soda, then dissolved in nitrobenzole at a temperature of 140° C and recrystallized. After recrystallization, a thick slurry in water is prepared and phlegmatized with montan wax.

Hexogen plant in Krummel had a capacity of 100 tons per month. In March 1944 the production was stopped due to the shortage of potassium salt.

Six vessels, made of V2A steel, are arranged in series, so that the overflow from the previous one goes into the following vessel. Each vessel is of five cubic meters capacity, and is equipped with a high speed mixer. Potassium salt is continuously introduced into the mixed acid, the necessary proportions between the salt and the acid being achieved in the

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fourth vessel. The two last vessels serve to complete the reaction and produce hexogen. The process is continuous. The nitration mass from the sixth vessel flows into a tank containing suspended hexogen and acid, the concentration of which is kept within the necessary limits to assure complete settling of hexogen crystals. The tank is followed by the second tank, in which the nitrous gases are removed. The mass then goes to vacuum filters. Hexogen is washed with water and the conveyor takes it to the second building. Here, hexogen is washed in wooden tanks with a cold 5 per cent soda solution. Washing solution is removed on vacuum filters, crystals are washed with water, filtered and dissolved in nitro-benzene from which they are recrystallized. Hexogen is then dryed with circulating 80°-100°C air. The capacity of the drying installation is about 180 tons per month.

Spent acid which contains about 25 per cent of HNO_3, 12 per cent H_2SO_4 and about 8 to 10 per cent Na_2SO_4 is regenerated. The acid is passed through a series of settling tanks to remove all explosive solids, which it still may contain. Then it is introduced in a column for a preliminary concentration. It goes then to Pauling ovens, where it is denitrated. The distillate is 40 to 45 per cent HNO_3, which is further concentrated to 99 per cent in the usual way with sulphuric acid. The residue consisting of potassium pyrosulphate, potassium bisulphate and sulphuric acid is in preparation of the nitration mixture. The solidification point of the residue is between 120-140° C.

In the KA process, hexamine dinitrate, which is made by quantitative reaction of hexamine and dilute nitric acid (about 50 per cent) is well dried and fed into acetic anhydride together with ammonium nitrate. This process is very much more economical (of ammonia and formaldehyde) and does not require concentrated nitric acid. The yield on the basis of formaldehyde is about twice that obtained by the SH process. The crystals of hexogen are carefully freed of acid by washing.

(3) PH Salt (Ethylene Diamine Dinitrate)

PH Salt is made by reacting ethylene diamine (from ethylene chloride and ammonia) with dilute nitric acid, evaporating and crystallizing the resultant salt. As nitration is not involved, highly concentrated nitric acid is not required. Because of its insenstivity, PH Salt was used as a filling for armor piercing shell.

(4) Penta (Penthrite, Pentaerythritol tetranitrate, PETN)

PETN is a high explosive used both in exploders to initiate detonation of large high explosive charges and also (mixed with wax) as the main burster charge for small calibre shells. It is used alone in the form of primacord, and to some extent in powders. It is made by nitrating pentraerythritol (made by condensation of formaldehyde and acetaldehyde) with mixed sulfuric and nitric acid.

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This is a batch process. Each batch is made up with 200 kgs of Penta-erythritol, C $(CH_2 OH)_4$, and nitrated with 1,000 kgs of acid.

Nitration is effected in nitrators with cooling coils, and the temperature is kept about 15-20° C. There are three nitrators. The principal reaction takes place in the first nitrator; after nitration in the second and third nitrators, the mass is diluted with water. After a total nitration of 40 minutes time for each charge, the product is filtered on vacuum filters. The spent acid contains 30 per cent HNO_3 and is reconcentrated. Unstable nitro-penta goes to the washhouse, where it is neutralized with a weak soda solution and washed for over an hour at 60° C, then it is vacuum filtered and washed again in cold water. This product is called raw nitro-penta.

The raw product is then dissolved in aceton. A small amount of soda is added to provide a weak alkaline reaction and the nitro-penta recrystalized. Aceton is recovered, distilled and reused. During the process of recyrstallization, the traces of the acid are removed and technically pure nitro-penta is obtained.

The product is slurried with water and phlegmatized with montan wax. Wax content is about 10 per cent. After filtering on vacuum filters, the phlegmatized nitro-penta goes to the dryers for seven hours at 70° C. After drying, it is mixed and goes for pressing in 125 to 200 ton hydraulic (oil or water) presses.

(5) Methriol Trinitrate

Methriol Trinitrate is chemically similar to PETN but has one less nitrate group. In other words it has one methyl and three methylenenitro groups bound to a central carbon atom. It was made on a pilot plant scale (5016 tons per month) from 1941 to 1945 at the Krummel plant. It is made by nitrating methriol (trihydroxymethyl, methyl methane) in the usual manner with mixed acids.

(6) Picric Acid (Trinitrophenol)

Picric acid, which may be used as such or as ammonium picrate, (explosive), is made by nitration of phenol with mixed acids. In practice the phenol is first sulfonated by reaction with concentrated sulfuric acid, and is then nitrated. Contact with metals must be avoided, because it reacts with metals to form extremely sensitive compounds.

(7) MAN Salt (Methyl Amine Nitrate)

The Germans adopted this compound as a substitute or additive for TNT when nitrogen became scarce in 1944. It was very economical of nitrogen and did not require highly concentrated nitric acid in its production.

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It was made by quantitative addition of dilute nitric acid to monomethyl amine, evaporating the solution and crystallizing the salt. The methyl amine was produced as a by-product of the manufacture of one of the war gases. The desired product was dimethyl amine, but an equilibrium mixture of the mono-, di-, and tri-methyl amines was produced by the methylation process. MAN salt was inferior to TNT but superior to ammonium nitrate as an explosive.

(8) Trinitroaniline and Dinitro Anisole

These are other additive explosives which were produced in small volumes. They are made by nitration of aniline and anisole, respectively.

(9) Dinitro Benzol - Dinitrobenzene

This material, which was used as an additive to more highly brisant explosives, was made by nitration of benzene with mixed acids.

(10) Hexa (Hexanitrodiphenylamine)

Hexa is made by the nitration of dinitrodiphenylamine in a manner very similar to the nitration of toluene. The starting material, dinitrodiphenylamine, is synthesized by chlorinating benzene to the monochlor derivative, nitrating to the dinitrodichlor-benzene, and reacting this with aniline.

(11) Tetryl. (Tetra, or Trinitrophenylmethylnitramine)

Tetryl is a highly brisant, powerful and sensitive explosive which is used particularly as an exploder to reinforce the flash from the detonator to the main high explosive charge in shells and bombs. The raw material, dimethylaniline, was normally supplied by chemical plants and dyeworks. It was first sulfated with concentrated sulfuric acid ata controlled temperature and then nitrated in the usual way. The solid tetryl is separated by filtration, washed with boiling water, centrifuged, dissolved in acetone and precipitated by addition of water.

(12) Nitroglycerin and Dinitrodiglycol (Nitroglycol DEGN)

Although these compounds are used in the manufacture of industrial high explosives, such as dynamite, their main application in the German military picture was as compounding agents for solventless (POL) nitrocellulose powders. Although the chemical reaction involved is esterification of a polyhydric alcohol with nitric acid, rather than strictly nitration as in the case of toluene, the essential chemical process is not greatly different. Mixed acids (e.g. 69 per cent H_2SO_4, 29 per cent HNO_3, and two per cent water) are used. The product separates as an oily liquid on the surface of the reaction mixture. The oil is separated

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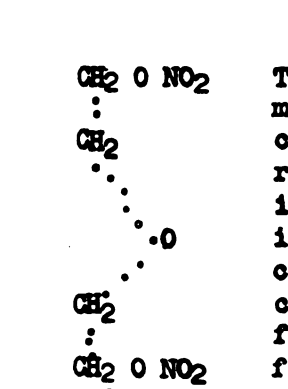
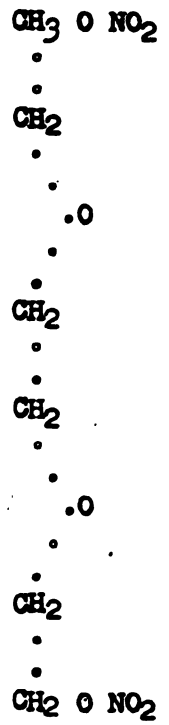
and purified by washing with water and dilute sodium carbonate solution. Both batch and continuous processes are used.

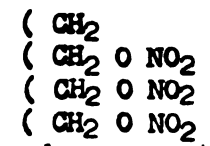
Production of Diglycol-Dinitrate



This is a batch process. The weighing of diglycol and mixed acids is done in the measuring house. From there, both components are separately piped by air-pressure to the nitration house. Acids are poured into the nitrator and glycol is introduced in a finely divided state. During the charging, the mass is violently mixed by compressed air, and kept cool by circulating cold salt solution in the coils. After completion of the reaction, the product (oil) is separated from the acids, in which it is insoluble; the acids are sent for regeneration and the acid product is washed with water and neutralized with soda. Then it is rewashed to remove excess soda. The product is tested by Abel-Test and stored. For use in the preparation of raw-powder paste, it is weighed in small masses and emulsified with water.

The production of Triglycol Dinitrate:



and of Methriol Dinitrate:  follows essentially the same procedure as outlined for Diglycol Dinitrate.

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(13) Myrol (Methyl nitrate)

This explosive was developed as a substitute for nitroglycerin for which it was equivalent for demolition purposes.

It is less poisonous than nitroglycerin. Its fumes affect the eyes, but its effects are of short duration.

Production of myrol is a continuous process carried out in a fractionating column with cap plates made of stairless steel. The process requires careful control of temperature. The raw materials are methanol and 60 per cent nitric acid. A mixture of 75 per cent methyl nitrate and 25 per cent methanol, having an eutectic at 50°C is produced. It explodes at 150° C. Pure methyl nitrate, distilled at 60° C is very dangerous to handle. It was made in Christianstadt on a small scale. A plant with production of 500 tons per month was built, but was not put in operation before the end of hostilities. It was intended to be used in V weapons and in double base powders.

(14) Ammonium Nitrate

The ammonium nitrate used as an extender for TNT and other high explosives may be produced in the explosives plant by direct reaction of Ammonia with dilute nitric acid, followed by crystallization and drying, or by reaction of ammonia and sodium nitrate. It may also be procured from outside sources as are the other extenders; sodium nitrate, calcium nitrate and calcium ammonium nitrate.

b. Powders - Propellants

By far the greater part of German powders was made from nitrocellulose. The main exceptions were a moderate production of nitroguanidine powder, mainly for high altitude flak, and a small production of black powder for powder trains in fuses, etc.

(1) Nitrocellulose

The Manufacture of nitrocellulose is dependent upon a source of rather pure cellulose. Bleached cotton linters are preferred, but owing to a lack of domestic supply of cotton, Germany was forced to use cellulose of wood origin. Wood (preferably beech) is sliced into thin chips and treated with caustic soda or calcium bisulfate under pressure. Coloring matter and other impurities are removed by bleaching. The excess bleaching a gent is drawn off and all soluble salts are removed by washing. The resultant cellulose is rolled into a thick crepe paper, which is later nitrated. The conditions of the nitration process are regulated according to the degree of nitration and hence the type of nitrocellulose desired. In general, the nitration is carried

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out by means of mixed acids as a batch process in the usual way. The nitrogen content of the product is controlled mainly by the concentration of the acid mixture; for example, a mixture of 62 per cent H_2SO_4, 24 per cent NNO_3, and 14 per cent water gives a product containing 12.3 per cent nitrogen and a mixture containing 71 per cent H_2SO_4, 21 per cent HNO_3 and eight per cent water gives nitro cellulose containing 13.1 per cent nitrogen. Loose scrolls of the crepe are immersed in the acid mixture at a controlled temperature. When the reaction is complete, the spent acid is removed from the bottom of the nitrator while cold water is run on at the same rate at the top. The product still retains considerable acid, which is removed by repeated boiling with water. The nitrocellulose is then reduced to a fine suspension in water to facilitate final washing. The resultant pulp is kept wet with about 20 per cent water for safety in storage and handling. The difficulty of washing residue acid from the nitrocellulose to which it adheres very tenaciously, results in a large wastage of sulphuric acid.

Nitrocellulose having a nitrogen content in the range 10.7 to 11.5 per cent is known as collodion cotton and is suitable for the production of celluloid plastics. Material used as a base for powders usually contains 11.5 to 12.7 per cent nitrogen. Gun cotton, which is used largely as a high explosive for demolition charges, etc., contains 13 to 13.6 per cent nitrogen.

It is evident, then, that the same process and the same plant equipment can be used for the production of nitrocellulose for plastics and for explosives and propellants. In many, if not most cases in the German set-up, the nitrocellulose was not manufactured in the powder plant but was shipped in as a wet paste, from an outside source.

(2) Nitrocellulose Powders

The manufacture of propellants from nitrocellulose comprises the removal of water, the incorporation of chemical stabilizers to permit safe handling and storage of the dry powder, and forming the final compound into a solid coherent mass so that combustion will be forced to take place at the surface. Plasticizing explosives, such as nitroglycerin or dinitrodiglycol may or may not be incorporated in the powder to give it added power. Powders containing the explosives are called double base powders. Various forms, such as strips, rods, tubes, discs, and flakes are made so that the rate of combustion and liberation of hot gases, as controlled by the ratio of surface to volume, can be selected to give best results for any particular weapon or projectile. It is obvious that most of the operations in a factory making powder from finished nitrocellulose are largely mechanical and involve the use of highly specialized machinery and considerable hand work.

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Two principal types of powders were made in Germany, namely, regular nitrocellulose powders, and POL (pulver ohne losungsmittels) or solventless cordite.

In the manufacture of plain nitrocellulose powders, the moist nitrocellulose pulp is dehydrated as much as possible by centrifuging and subsequent washing with alcohol. The stabilizer, such as diphenylamine or centralite, and any necessary plasticizer are then added along with another solvent, such as ether or acetone, which with the alcohol already present will render the mass pliable and plastic. The whole mass is then thoroughly mixed and rolled or pressed into sheets, or extruded through dies. The sheets, cords or tubes are then dried, with or without cutting to the final form in special steam-heated ovens over a period of perhaps a week. The solvents are recovered from the air circulated through the drying ovens. Each of the above steps, namely, initial drying, mixing, rolling, and final drying, is conducted in a separate building or series of buildings.

(3) POL Powder or Solventless cordite

In the manufacture of these powders the nitrocellulose is rendered plastic without the use of added solvent. The process is particularly suitable for the preparation of large cords or sticks of cordite for rocket propulsion as it is practically impossible to remove solvents from the interior of large plastic masses. Sufficient plasticity for forming is obtained by using somewhat larger quantities of the nitroglycerin or diethyleneglycoldinitrate, and by using a specially chosen plasticizer such as diethyldiphenylurea, so that the finished product has sufficient rigidity at ordinary temperatures, but can be formed in the manufacturing process at 50 to 800 C.

Nitrocellulose in the form of a water slurry is mixed with liquid drops of nitroglycerin, or the diglycol dinitrate which wet and adhere to the nitrocellulose fibers. The finely powdered plasticizer is then added and the whole mass is mixed rigorously. Water is removed by centrifuging or filtering, and the mass is dried in a stream of warm air. The mass is then consolidated by rolling on heated rolls and is extruded through dies while still hot.

(4) Nitroguanidine.

Nitroguanidine, required for high altitude flak, was made by nitration of guanidine dinitrate with a mixture of concentrated sulfuric and nitration grade nitric acid. It was usually compounded with diethylene glycol dinitrate and gelatinizing agents. It was also compounded with nitrocellulose to suppress muzzle flash. Many blended powders and explosives have been made of the above components. An example is nipolyte, which is 90 pts hexogen or penta, 10 pts DEGN, 25 pts nitrocullulose and

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25 pts centralite. It was prepared in extruded form for clearance of mine fields and demolitions. For composition of various mixed powder explosives see Exhibit Q.

(5) Black Powder - Gunpowder

Black powder is a mechanical mixture of three basic components, namely, saltpeter, charcoal and sulphur. The proportions vary with the purpose, but a typical mixture might be 75 per cent potassium nitrate, 15 per cent charcoal and 10 per cent sulphur. The components are finely ground in separate mills, and after rough mixing in a mechanical mixer are moistened and thoroughly mixed in a mill. The milled cake discharged from this mill is reduced to a coarse meal by passing between gunmetal rollers and is then converted to press cake in a hydraulic press at about 400 lb per square inch. This cake is broken with wooden mallets, crushed between inclined rollers, and graded to size by means of screens. The final graded products are dried by prolonged heating at 40° C. This powder is usedin propellent ignition systems to transmit and reinforce the flash from the percussion cap or detonator to the main charge of cordite and for delay trains in fuses for shells and bombs. The rate of burning is slow and can be controlled accurately by grain-size and degree of compacting.

3. CHARACTERISTICS OF POWDER AND EXPLOSIVES PLANTS AS BOMBING TARGETS

Powder and explosive plants are generally spread out over a large area and the more hazardous operations are dispersed in many small units isolated from each other by sufficient distance that a catastrophe in one will not endanger others. The proportion of built over area is therefore small, although the plant may comprise several hundred buildings. The number and character of the buildings is governed to some extent by the operations conducted in the plant.

Nitration buildings in German plants varied in design with the explosive produced and the hazards involved. The nitration of cellulose, which in a few exceptional cases was conducted in the powder plants, involved relatively little explosion hazard. The buildings in which nitrocellulose was made were very much larger and higher than those for high explosives such as TNT or nitroglycerin. They resembled large rectangular machine shops. They were liberally provided with roof ventilators but were seldom mounded or provided with blast walls. The plants for the manufacture of the finished propellants, on the other hand, were characterized by a large number of comparatively small buildings well dispersed and generally mounded. This was particularly true of the buildings in which the storing or drying took place. Factories making finished powder had considerable tank storage capacity and large absorbing towers and stills for solvent recovery. Buildings in which high explosives were made by nitration usually were provided with a

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higher degree of protection. TNT and picric acid were made in medium sized sheds provided with denitrating columns alongside them. The mononitration step involved very little hazard and the buildings were very seldom mounded. Buildings housing the subsequent nitration were generally, and the washing and purification houses always, protected by earth mounds. German plants tended to concentrate the TNT nitration in two series of nitrators, so that the crippling of either one would wipe out 50 per cent of the plant production. Picric acid buildings were sometimes mounded and generally well separated. Buildings in which Tetryl, Hexogen, and Penta were made were invariably well protected by earth mounds and blast walls. Probably the greatest hazards were involved in the manufacture of nitroglycerin, nitroglycol, and dithylene blycol dinitrate. Buildings for this operation were small and very heavily mounded and were so clustered in small groups that the group had the appearance of being one large mound or hill.

All plants in which nitrations were conducted had large plants for the recovery and concentration of sulfuric and nitric acids. Plants making finished propellents from nitrocellulose made elsewhere did not need such equipment. Several of the explosives plants had buildings housing filling lines for hand grenades, shells, bombs and warheads for V-weapons. In the case of TNT, the fillings were either moulded or poured. In the first case, the mixture of TNT and extender such as ammonium nitrate, phlegmatizer and wax or binder was molded under pressure in a hydraulic press. The mouldings were wrapped in paper and packed for shipment. In the second case, TNT and ammonium nitrate kept in a molten state in separate tanks or pipes, were blended together and poured immediately into the shell or bomb. After cooling and solidification, cores were drilled out for burster charges, etc., where necessary. Other explosives which did not fuze readily were filled by pressure compacting. Buildings housing filling lines are usually long low structures.

As process steam was used in all propellant and explosives plants, a common feature was one or more large steam generator plants. Any serious damage to the boiler houses or steam distribution system would have stopped operations in the portions of the plant affected.

Many of the German plants were dispersed in forests. Gas for concentration of acid, etc., was piped from the nearest city. Although most factories had their own power plants, arrangements were made to obtain current from the grid system when needed.

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UNITED STATES STRATEGIC BOMBING SURVEY

LIST OF REPORTS

The following is a bibliography of reports resulting from the Survey's studies of the European and Pacific wars. Those reports marked with an asterisk (*) may be purchased from the Superintendent of Documents at the Government Printing Office, Washington, D. C.

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*1 The United States Strategic Bombing Survey: Summary Report (European War)
*2 The United States Strategic Bombing Survey: Over-all Report (European War)
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(By Division and Branch)

*4 Aircraft Division Industry Report
5 Inspection Visits to Various Targets (Special Report)

Airframes Branch

6 Junkers Aircraft and Aero Engine Works, Dessau, Germany
7 Erla Maschinenwerke G m b H, Heiterblick, German
8 A T G Maschinenbau, G m b H, Leipzig (Mockau), Germany
9 Gothaer Waggonfabrik, A G, Gotha, Germany
10 Focke Wulf Aircraft Plant, Bremen, Germany
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12 Dornier Works, Friedrichshafen & Munich, Germany
13 Gerhard Fieseler Werke G m b H, Kassel, Germany
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Aero Engines Branch

15 Bussing NAG Flugmotorenwerke G m b H, Brunswick, Germany
16 Mittel-Deutsche Motorenwerke G m b H, Taucha, Germany
17 Bavarian Motor Works Inc, Eisenach & Durrerhof, Germany
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21 Vereinigte Deutsche Metallwerke, Hildesheim, Germany
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23 Aluminiumwerk G m b H, Plant No. 2, Bitterfeld, Germany
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32 A Detailed Study of the Effects of Area Bombing on Hamburg
33 A Detailed Study of the Effects of Area Bombing on Wuppertal
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37 A Detailed Study of the Effects of Area Bombing on Darmstadt
38 A Detailed Study of the Effects of Area Bombing on Lubeck
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43 Hanover Field Report
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*50 Optical and Precision Instrument Industry Report

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52 Mayer and Schmidt, Offenbach on Main, Germany

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*55 Machine Tool Industry in Germany
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60 V-Weapons (Crossbow) Campaign
61 Air Force Rate of Operation
62 Weather Factors in Combat Bombardment Operations in the European Theatre
63 Bombing Accuracy, USAAF Heavy and Medium Bombers in the ETO
64 Description of RAF Bombing
64a The Impact of the Allied Air Effort on German Logistics

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*64b The Effects of Strategic Bombing on German Morale (Vol I and Vol II)

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68 Gutehoffnungshuette, Oberhausen, Germany
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73 Friedrich Krupp A G, Borbeck Plant, Essen, Germany
74 Dortmund Hoerder Huettenverein, A G, Dortmund, Germany
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*78 Tank Industry Report
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81 Adam Opel, Russelheim, Germany
82 Daimler Benz-Gaggenau Works, Gaggenau, Germany
83 Maschinenfabrik Augsburg-Nurnberg, Nurnberg, Germany
84 Auto Union A G, Chemnitz and Zwickau, Germany
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87 Voigtlander, Maschinenfabrik A G, Plauen, Germany
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92 German Submarine Industry Report
93 Maschinenfabrik Augsburg-Nurnberg A G, Augsburg, Germany
94 Blohm and Voss Shipyards, Hamburg, Germany
95 Deutschewerke A. G, Kiel, Germany
96 Deutsche Schiff und Maschinenbau, Bremen, Germany
97 Friedrich Krupp Germaniawerft, Kiel, Germany
98 Howaldtswerke A. G, Hamburg, Germany
99 Submarine Assembly Shelter, Farge, Germany
100 Bremer Vulkan, Vegesack, Germany

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102 Friedrich Krupp Grusonwerke A. G Magdeburg Germany
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104 Henschel & Sohn, Kassel, Germany
105 Rheinmetall-Borsig, Dusseldorf, Germany
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*111 Powder, Explosives, Special Rockets and Jet Propellants, War Gases and Smoke Acid (Ministerial Report #1)
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113 The German Oil Industry, Ministerial Report Team 78
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131 Schoenebeck Explosive Plant, Lignose Sprengstoff Werke G m b H, Bad Salzemen, Germany
132 Plants of Dynamit A G, Vormal, Alfred Nobel & Co, Troisdorf, Clausthal, Drummel and Duneberg, Germany
133 Deutsche Sprengchemie G m b H, Kraiburg, Germany

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134 Over-all Economic Effects Division Report
Gross National Product — Special papers which together comprise the above report
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Herman Goering Works — Special papers which together comprise the above report
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134a Industrial Sales Output and Productivity

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135 Villacoublay Airdrome, Paris, France
136 Railroad Repair Yards, Malines, Belgium
137 Railroad Repair Yards, Louvain, Belgium
138 Railroad Repair Yards, Hasselt, Belgium
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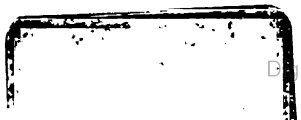

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